REPORT NUMBER: WI-11-01

POLLUTANT LOADINGS TO STORMWATER RUN-OFF FROM HIGHWAYS:

THE IMPACT OF A FREEWAY SWEEPING PROGRAM

FINAL REPORT

RESEARCH PROJECT I.D. # 0092-45-82

WISCONSIN DEPARTMENT OF TRANSPORTATION

JUNE, 2002

POLLUTANT LOADING TO STORMWATER RUNOFF

FROM HIGHWAYS:

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WISDOT HIGHWAY RESEARCH STUDY #97-01

PROJECT I.D. #0092-45-82

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16. Abstract

The Wisconsin Department of Transportation is required to control the quality of storm water runoff from the state highway system in response to the EPA National Pollution Discharge Elimination System and the Wisconsin Department of Natural Resources regulations. A method to control roadway storm water runoff pollutants on urban freeways is by the use of street sweepers to remove pollutants before they enter storm water runoff and runoff control structures. This study evaluates the effectiveness of an improved highway sweeping program using a high efficiency sweeper as a best management practice (BMP) for reducing pollutants in urban highway storm water runoff.

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ABSTRACT

The Wisconsin Department of Transportation is required to control the quality of storm water runoff from the state highway system in response to the National Pollution Discharge Elimination System and Wisconsin Department of Natural Resources regulations. A method to control roadway storm water runoff pollutants on urban freeways is by the use of street sweepers to remove pollutants before they enter storm water runoff and runoff control structures. This study evaluates the effectiveness of an improved highway sweeping program as a best management practice (BMP) for reducing pollutants in urban highway storm water runoff.

EXECUTIVE SUMMARY

POLLUTANT LOADINGS TO STORMWATER RUNOFF FROM HIGHWAYS: THE IMPACT OF A FREEWAY SWEEPING PROGRAM

The Wisconsin Department of Transportation (WisDOT) is required to control the quality of storm water runoff from the state highway system. One method to control roadway runoff from urban freeway sections is the use of street sweeping equipment to remove pollutants before they enter the freeway storm water system. This study evaluated the effectiveness of an improved highway sweeping program using a high efficiency sweeper to reduce both dirt levels on freeway pavement and pollutants in the runoff from an urban freeway roadway surface.

This improved sweeping program is proposed as a best management practice (BMP) to accomplish the storm water regulations of the Wisconsin Department of Natural Resources (Administrative Code NR 216) and the Environmental Protection Agency (EPA National Pollution Discharge Elimination System-NPDES).

A research project to study the effectiveness of an improved sweeping program on an urban freeway section was proposed by the WisDOT Bureau of Highway Operations to the WisDOT Council on Research. The project was approved for funding in May, 1996 and the field portion of the study was completed in September, 2000. The study is believed to be the most complete attempt to document the use of a high efficiency sweeper program on an urban freeway section.

The study was performed through a partnership of WisDOT, WDNR, and the United States Geological Survey (USGS).

The research process used a paired basin approach using a test section that was swept once per week and a control section that was not swept during the study period. The research field sampling time frame extended from March, 1999 through September, 2000, a nineteen-month period. The study test and control sections were located on I.H. 894 in Milwaukee County, Wisconsin. The test section extended from Oklahoma Avenue Dakota Street and contained a drainage area of 4.56 acres. The control section was from National Avenue to Cleveland Avenue and contained a drainage area of 5.51 acres. Field samples were collected by USGS and WisDOT District 2 staff from the test and control sections. Samples of highway surface dirt were collected using a vacuuming process and samples of storm water runoff were collected with refrigerated automatic point samplers.

Based on data collected and analyzed during the study, it was calculated that a once per week freeway sweeping program using a high efficiency can be an effective storm water runoff best management practice (BMP) for an urban freeway section. Concentration levels of toxicity characteristics did not exceed current standards. Material collected from a sweeping program should not require any special disposal restrictions.

A benefit/cost analysis was not performed as a part of this study.

The findings from this study indicate that freeway sweeping with a high efficiency sweeper can be a best management practice for the control of storm water runoff pollutants from urban freeway sections. The results of the study indicate that the WisDOT should support the purchase and use of high efficiency sweepers by county highway departments responsible for maintaining urban freeway sections. Guidelines will be developed for the purchase and use of high efficiency sweepers. The effectiveness of other sweeping frequency schedules will be studied. The WisDOT Bureau of Highway Operations will be responsible for the coordination of an improved sweeping program in partnership with WisDOT District Operations offices and county highway departments. Results of this research project will be communicated to these partners by the Bureau of Highway Operations through the use of a maintenance manual guideline and regularly scheduled WisDOT District Operations office and county highway department meetings.

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I. INTRODUCTION

A. BACKGROUND

The Wisconsin Department of Transportation WisDOT is required to control the quality of storm water runoff from the state highway system as part of the National Pollution Discharge Elimination System (NPDES) and Administrative Rule WDNR 216 on storm water regulations. One method to control roadway runoff is the use of street sweeping to remove pollutants before they are entrained in storm water runoff. This could be a good option since land for runoff control facilities is unavailable or prohibitively expensive and structural Best Management Practices (BMP's) can be expensive. If highway sweeping were shown to be an effective method at reducing pollutants in storm water runoff, WisDOT may only need to increase sweeping frequency and support the purchase of high efficiency street sweepers. This study evaluated the effectiveness of an improved highway sweeping program at reducing dirt on the pavement and pollutants in runoff from an urban highway roadway surface.

A research project to study the effectiveness of an efficient sweeping program on an urban freeway section was proposed by the WisDOT Bureau of Highway Operations to the WisDOT Council on Research in January 1996 and the project was approved for funding in May 1996. (A copy of the proposal is included in the Appendix)

B . STUDY OBJECTIVES

This study intended to document the effectiveness of a high efficiency street sweeper used on an urban freeway section to control the quality of storm water runoff from the pavement surface and to document the use of a high efficiency street sweeper as a storm water best management practice for compliance with Wisconsin Administrative Code NR216 and Chapter 283, Wisconsin Statutes.

(Refer to the Memorandum of Understanding between WisDOT and WDNR in the Appendix)

II. STUDY DESIGN

The study evaluation work plan (refer to the Appendix) outlined the organization of the study and the required tasks.

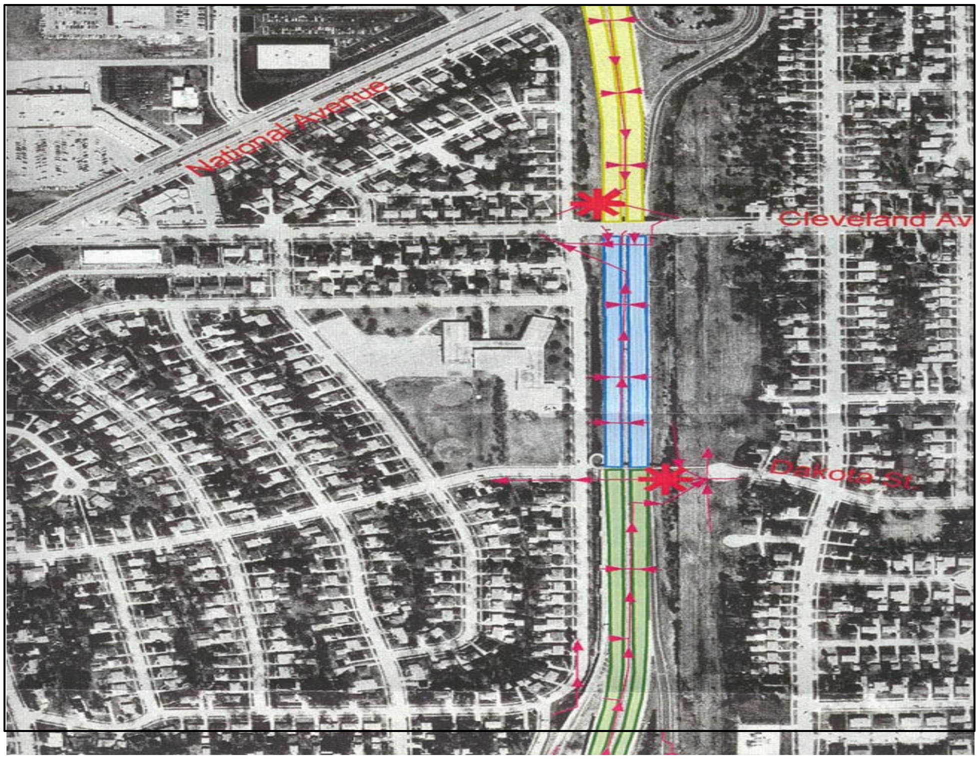
A. Study Test and Control Section Sites

The test and control section area selected was one of the busiest stretches of roadway in the state of Wisconsin on Interstate 894 in West Allis, Wisconsin just west of Milwaukee. The average daily traffic count (ADT) during the study period was 64,900 in the east bound direction and 69,000 in the west bound direction for a combined ADT of 133,900 in both the control and test basins since there are no entrance or exit ramps between the two basins. The two basins were located between National Avenue and Oklahoma Avenue with a buffer section between the two. The pavement on this stretch of freeway is concrete last resurfaced in the mid-1990's and considered in generally good condition for pavement of this age. The shoulders are concrete and were installed in the late 1970's. In between the test and control basins, a 1,000 foot buffer section was designated. (Vehicles entering either the test or control basin would then be traveling over pavement that had been swept in the same manner as the pavement in the basin that the vehicle was entering. The purpose of this was so that the dirt the vehicle 'pulled' into the basin by its wake would be comparable to the study basin). Note that no sweeping activities were performed in the control section.

Figure 1. Diagram of Study Area

The test basin was located between Oklahoma Avenue and Dakota Street and had a drainage area of 4.56 acres. This area is comprised of 4.31 acres of highway surface, 1.56 acres of which is shoulder and 2.67 acres is driving lane surface area; 0.08 acres was found in the median. In addition, 0.25 acres is grassy, non-highway area. (Figure 2, p. 3).

The control basin was located between National Avenue and Cleveland Avenue and had a drainage area of 5.51 acres. The area is comprised of 3.46 acres of highway surface, 1.45 acres of which is shoulder and 1.95 acres is driving lane surface area; 0.06 acres was found in the median. In addition, 2.05 acres is grassy, non-highway area.



LEGEND: * = Field Sampling Station

----→ = Storm Sewer Collection System

Green Section = Test Section

Blue Section = Buffer Section

Yellow Section = Control Section

Figure 2. Aerial Photo of the Study Area

B. High Efficiency Street Sweeper Unit

A Schwarze Industries EnviroWhirl EV2 street sweeper was used for the study. Product literature on the street sweeper unit and photos of the unit in use are included in the Appendix. A once per week sweeping schedule was carried out.

Because of the slow operating and travel speed of the street sweeper, only the shoulder areas of the basins were swept. Of this swept area, the EnviroWhirl was always used to sweep the outside shoulder and was used on every other sweep of the inside shoulder. The mechanical sweeper that Milwaukee County currently uses was used on the alternate sweepings of the inside shoulder. The result of this sweeping protocol was that only 34 percent of the area in the test basin was swept. The EnviroWhirl swept 19.5 percent every week and the full 34% every other week. No other sweeping frequencies were attempted during the study.

C. Sampling Equipment and Processing

1. Street Dirt Collection and Processing

Samples of street dirt were collected from the outside shoulders using a 6-in. wide wand attached to a 9-gal. Milwaukee wet/dry vacuum. During each sample collection, the wand was pulled from the curb to the edge of the traffic lane, twenty four times in each basin, twelve in each traffic direction (similar to the technique described by Pitt (1) and Bannerman (2)).

The dirt samples were weighed, dried at 105^0C, and then reweighed. The samples were then sent to the University of Wisconsin Department of Geology Quaternary Laboratory in Madison, Wisconsin, for sieving into 6.37-2.0 mm, 2.0-1.0 mm, 1000-500 um, 500-250 um, 250-125 um, 125-63 um, 63-25 um, and < 25 um size fractions.

Two samples of the dirt collected by the EnviroWhirl street sweeper were also brought to the Wisconsin State Laboratory of Hygiene for Toxicity Characteristic Leachate Procedure (TCLP) analysis.

2. Precipitation

Continuous precipitation data was collected with a tipping bucket rain gage. A Campbell Scientific CR10 data logger was used to record rainfall data. The rain gages used were not designed to measure snowfall so precipitation values from March 10-14, 1999 and December 14, 1999 to April 11, 2000 should be viewed with some skepticism. Occasionally data from the Mitchell International Airport National Weather Station, which is located about 8 miles southeast of the study area, was used.

The precipitation data were compiled and various statistical summaries computed including total precipitation, maximum 15 and 30 minute intensities, antecedent dry time, and erosivity index.

3. Flow

Area velocity flow meters were the primary method used to measure the flow in the pipes. A probe was mounted at the bottom of the pipes to measure water level and velocity. The probes at both sites measured velocity using Doppler-type technology. Water level was measured at the control site using a bubbler-type probe and at the test site using a submerged pressure transducer type probe. In addition to area–velocity probes, an independent bubbler was installed in the pipes as a back up and verification of the water level measurement.

During the study period, the data showed that the two sites were giving significantly different flow rates for the same events. One possible explanation for this difference is that 37 percent of the control site drainage area was grass while the test site was only 6 percent grass. In addition, some of this discrepancy may be due to the different type of flow meters employed. A submerged pressure transducer was used to determine stage in the test site pipe and a bubbler type transducer was used at the control site. This discrepancy did not affect the flow composite sampling however since the sub-sample volume used to trigger samples was set independently and the difference in measured flow rates was accounted for.

Several steps were taken to achieve the most accurate flow estimate possible. Velocity data from the Doppler probes frequently showed periods where data were unreliable. The stage data on the other hand looked reliable for most periods. Therefore stage discharge relationships were determined, since they eliminated the need to use unreliable velocity data. The stage-discharge relationships were developed by eliminating periods where the velocity data was questionable and fitting a best-fit curve through a stage versus discharge scatter plot of the remaining data. To make the ratings more accurate, at the end of the study, an independent flow meter (Marsh-McBirney Flow-Tote) using a different technology (electromagnetic) was installed at the test site to collect data from a few events. These data were limited, but confirmed the rating at several points. Since the rating agreed with the limited data available, the rating seemed reasonable.

4. Runoff Sampling

Flow composite water quality samples were collected with refrigerated automatic point samplers. These samples were initiated by the station data logger, based on flow rates. Samples were collected in a manner that resulted in flow composite samples. Flow composite sampling yields a single sample that which when analyzed results in a single Event Mean Concentration (EMC) represents the entire runoff event. The samples were analyzed for the constituents listed in Table 1 (page 6).

Because of budgetary restraints, only suspended solids, suspended sediment, total copper and total zinc were analyzed for every event. The remaining constituents were analyzed for approximately one-quarter of the events.

Constituent	Laboratory[1]	Method[2] or Reference[3]
Chemical Oxygen Demand	WSLH	EPA 410.4
Ammonia-Nitrogen	WSLH	SM4500H
NO2 + NO3	WSLH	SM4500F
Total Phosphorus	WSLH	SM4500PB
Dissolved Phosphorus	WSLH	SM4500PF
Suspended Solids	WSLH	SM2540D
Total Dissolved Solids	WSLH	SM2540C
Chloride	WSLH	SM4500CL
Total Recoverable Copper	WSLH	EPA 200.9
Dissolved Copper	WSLH	SM3113B
Total Recoverable Zinc	WSLH	EPA 200.9
Dissolved Zinc	WSLH	SM3113B
Suspended Sediment	USGS - ISL	Guy (1969)
Particle Size Analyses:		
Sand-Silt Split	USGS - ISL	Guy (1969)
Visual Accumulation Tube	USGS - ISL	Guy (1969)
Sedigraph	USGS - ISL	Guy (1969)

[1] USGS – ISL, U.S. Geological Survey - Iowa Sediment Laboratory;

WSLH, Wisconsin State Laboratory of Hygiene

[2] EPA (1979); and SM, Standard Methods, American Public Health Association and others, 1989.

[3] Guy (1969)

Table 1. Constituents Analyzed for in Runoff Samples

5. Load Calculations

Once the stage-discharge relationships were finalized, the event discharges were summarized and then multiplied by the EMC's to calculate event loads (Tables A1 and A2, Appendix).

Table 2. Summary statistics for runoff concentrations at both the test and control sites during sweeping and non-sweeping periods

	Test site summary statistics for samples collected during:											
	non-sweeping periods						sweeping periods					
	n	mean	median	geomean	standard deviation	Coefficient of variation	n	mean	median	geomean	standard deviation	coefficient of variation
COD (mg/L)	5	49.2	50.0	47.8	13.4	0.27	5	158.1	97.0	120.7	153.4	0.97
Total Solids (mg/L)	2	923.0	923.0	658.3	-	-	5	2551.4	3090.0	1436.7	2162.1	0.85
TSS (mg/L)	19	196.8	95.0	117.4	272.8	1.39	22	259.8	211.0	204.7	185.7	0.71
S. Sed (mg/L)	16	564.7	228.0	284.8	782.3	1.39	22	669.1	358.0	366.6	838.7	1.25
Diss. NH3 (mg/L)	5	0.5	0.4	0.4	0.3	0.60	5	0.7	0.6	0.6	0.3	0.50
Total NH3 + org. N (mg/L)	5	1.3	1.1	1.2	0.5	0.41	5	1.6	1.5	1.5	0.5	0.32
Diss. NO2+NO3 (mg/L)	5	0.8	0.4	0.6	0.8	0.95	5	0.7	0.7	0.7	0.1	0.16
Total P (mg/L)	5	0.2	0.2	0.2	0.1	0.41	5	0.3	0.3	0.2	0.3	0.85
Diss. Ortho-P (mg/L)	5	0.0	0.0	0.0	0.0	1.10	5	0.1	0.1	0.0	0.0	0.72
Total Ca (mg/L)	5	106.6	39.0	52.4	164.3	1.54	5	78.6	44.0	61.8	63.1	0.80
Total Mg (mg/L)	5	50.0	12.0	21.3	83.9	1.68	5	23.6	16.0	17.9	22.5	0.95
Diss. Cl (mg/L)	11	438.5	39.5	68.8	1002.6	2.29	8	2013.9	860.0	272.1	3332.8	1.65
Diss. Cu (mg/L)	5	9.6	7.3	8.6	5.9	0.62	5	119.4	17.0	46.1	175.2	1.47
Diss Zn (ug/L)	5	24.6	21.0	22.3	13.2	0.54	5	411.4	64.0	115.8	633.1	1.54
Total Zn (ug/L)	19	319.8	230.0	253.3	263.3	0.82	22	415.5	345.0	367.0	270.3	0.65
Total Cd (ug/L)	5	1.0	0.6	0.8	0.7	0.74	5	2.4	1.6	1.6	2.5	1.04
Total Pb (ug/L)	5	68.6	35.0	45.5	79.9	1.17	5	77.9	38.0	50.0	96.6	1.24
Total Cu (ug/L)	19	69.5	61.0	60.1	43.0	0.62	22	88.4	70.0	74.3	78.4	0.89
Total Hardness (ug/L)	5	469.4	170.0	222.3	744.7	1.59	5	292.0	180.0	229.8	243.2	0.83

	Control site summary statistics for samples collected during:											
	non-sweeping periods						sweeping periods					
	n	mean	median	geomean	standard deviation	cofficient of variation	n	mean	median	geomean	standard deviation	cofficient of variation
COD (mg/L)	5	49.0	45.0	48.3	9.62	0.20	5	148.9	110.0	119.9	125.76	0.84
Total Solids (mg/L)	5	346.0	152.0	220.7	444.25	1.28	5	2474.2	3270.0	1625.0	1790.07	0.72
TSS (mg/L)	18	107.8	91.0	85.3	69.21	0.64	22	193.3	135.0	163.9	146.35	0.76
S. Sed (mg/L)	18	190.1	104.5	114.4	242.94	1.28	22	362.8	248.8	232.8	376.04	1.04
Diss. NH3 (mg/L)	5	0.5	0.5	0.5	0.14	0.28	5	0.6	0.8	0.3	0.44	0.76
Total NH3 + org. N (mg/L)	5	1.3	1.2	1.2	0.34	0.27	5	1.5	1.9	1.4	0.67	0.44
Diss. NO2+NO3 (mg/L)	5	0.7	0.5	0.6	0.57	0.77	5	0.8	0.8	0.8	0.22	0.27
Total P (mg/L)	5	0.1	0.1	0.1	0.04	0.32	5	0.3	0.2	0.3	0.22	0.72
Diss. Ortho-P (mg/L)	5	0.0	0.0	0.0	0.01	0.37	5	0.0	0.0	0.0	0.01	0.82
Total Ca (mg/L)	5	31.2	29.0	25.9	22.52	0.72	5	79.5	49.0	66.5	53.96	0.68
Total Mg (mg/L)	5	13.3	13.0	11.1	9.08	0.68	5	24.7	21.0	20.8	16.67	0.68
Diss. Cl (mg/L)	12	511.9	36.3	56.9	1476.43	2.88	9	2086.0	56.4	247.0	4188.05	2.01
Diss. Cu (mg/L)	5	9.9	8.0	9.2	4.61	0.47	5	151.2	22.0	49.0	263.54	1.74
Diss Zn (ug/L)	5	25.4	21.0	24.4	8.44	0.33	5	398.1	110.0	155.7	624.13	1.57
Total Zn (ug/L)	18	212.6	185.0	186.6	116.72	0.55	22	367.3	285.0	310.2	285.24	0.78
Total Cd (ug/L)	6	28.8	0.5	1.4	69.18	2.40	5	2.4	2.0	1.8	2.16	0.91
Total Pb (ug/L)	5	25.6	26.0	25.2	5.13	0.20	5	80.4	42.0	54.3	90.40	1.12
Total Cu (ug/L)	18	56.8	56.0	50.5	30.20	0.53	22	103.7	79.5	81.9	118.53	1.14
Total Hardness (ug/L)	6	118.0	97.0	93.6	92.73	0.79	5	298.0	210.0	251.8	202.16	0.68

when 2 concentrations were available due to replicate sampling, the average was used
events 5, 6 & 7 eliminated due to construction activities
events 34, 41, 42 & 47 eliminated due to poor sampling

Definitions

Dis. - Dissolved	Ca - Calcium
COD - Chemical Oxygen Demand	Mg - magnesium
TSS - Total Suspended Residue	Cl - chloride
S.Sed. - Total Suspended Sediment	Cu - copper
NH3 - ammonia	Zn - zinc
org. N - organic nitrogen	Cd - cadmium
NO2 + NO3 - nitrate + nitrite	Pb - lead
P - phosphorus	n - number of sample results used to compute statistics

6. Median Runoff

Near the end of the project an attempt was made to gather information to assess the impact of the runoff from the area between the center jersey barriers. A one foot long piece of 8 inch diameter plastic PVC pipe was cut in half the long way and installed at a median inlet to act as a trough where an automatic water quality sampler with 24 discrete sample collection bottles collected runoff samples. A tarp was mounted 6 inches above the inlet grate to prevent rainfall from falling directly into the trough. This sampler was interfaced with the data logger so that a sample was triggered at both the station and median samplers concurrently. The median samples were analyzed for total suspended solids and the amount of water in the various sample bottles was noted. The amount of water in the sample bottles was used to attempt to estimate when runoff was occurring in the median and how much.

7. Traffic Counts

Traffic count data were collected using continuous recording traffic counters, which recorded 15-minute vehicle counts in both traffic directions. These data were then summarized for runoff and sampling periods.

8. Quality Assurance/Quality Control

Quality assurance/quality control samples were collected from the automatic water quality samplers and processed identically to event samples. Four blank samples were collected from each site during the monitoring period. Each blank sample was analyzed for the same constituents as the runoff samples (Table 1, page 6). The blank samples were used to evaluate the integrity of the runoff samples, to identify whether sample contamination existed, and, if so, to identify possible sources of sample contamination. In addition to blank samples, several replicate analyses were performed. Results from these blank and replicate analyses can be found in Tables 5, 6 and 7 (p.p. 18-21)

The rain gages were also calibrated four times during the study by using a rain gage calibrator, which slowly dripped a known volume of water through the gages and comparing the depth of water registered to the depth that should be observed for that volume of water. The rain gages were then adjusted to register the correct depth.

Photos of the sampling equipment are included in the Appendix.

D. Field Sampling Plan

A copy of the complete field sampling plan is also included in the Appendix.

III. DATA COLLECTION AND RESULTS

A. Elimination of Data Due to Construction Debris

In May of 1999, utility construction was initiated in the freeway right-of-way in the study area. The construction was concentrated mostly in the buffer section but did reach slightly into both the test and control sections. As a result of this utility construction there was some additional dirt on the road surfaces until the vegetation was reestablished (Figure 3). The data from this period, May 5, 1999 through June 10, 1999 (Events # 5, 6, 7), appeared unusually high so was eliminated from the analysis.

Figure 3. Photo Depicting the Utility Construction in the Test Area

B. Highway Dirt

Data from the highway dirt vacuuming and sieving are presented in Tables A3 and A4 (Appendix). These data were used to show the change in dirt loads on highway surfaces before and after sweeping (Figures 4 and 5, p.p. 11-12). Although there were not enough of these data points for statistical testing, these plots (Figures 4 and 5) seem to indicate that there was some benefit to the sweeping operation.

Table 3 (page 12) shows particle size data from dirt collected by the EnviroWhirl.

Results from the TCLP analysis of the highway dirt collected by the EnviroWhirl are in Table 4 (page 13). None of the results exceeded WDNR Administrative Code NR605.08 standards.

A comparison of suspended sediment samples obtained from the control sections versus samples collected from the test section is shown in Figure 6 (page 14). Discussion of this data can be found in Section VII-Discussion (page 33).

A one time vacuuming across all three lanes of traffic and the “breakdown” lanes was considered in the work plan to determine the particle build up across the entire cross section of the test area in order to verify the assumption that the majority of material deposited on the pavement will migrate to the shoulder areas. Due to scheduling and traffic volume issues, the vacuuming of all three lanes was not performed.

Results from the analysis of the constituents of the water samples collected from the pavement in the control and test sections obtained during both sweeping and non-sweeping periods are contained in Table 2 (page 7)

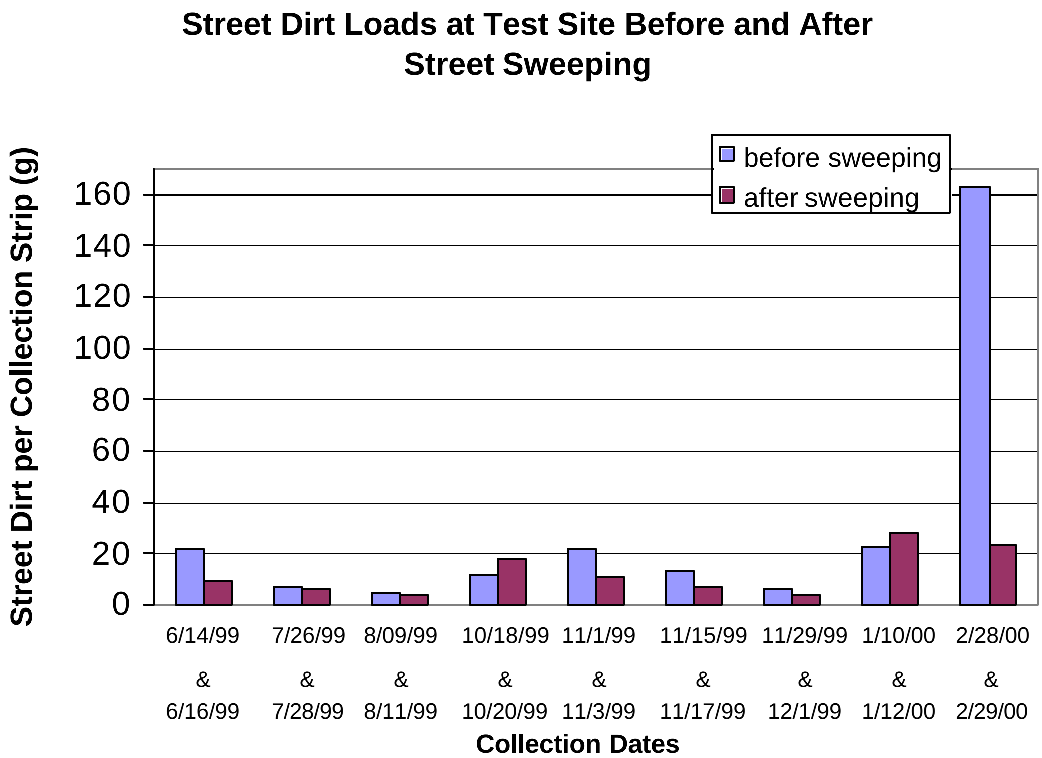


Figure 4. Highway Dirt Loads at Test Site Before and After Sweeping.

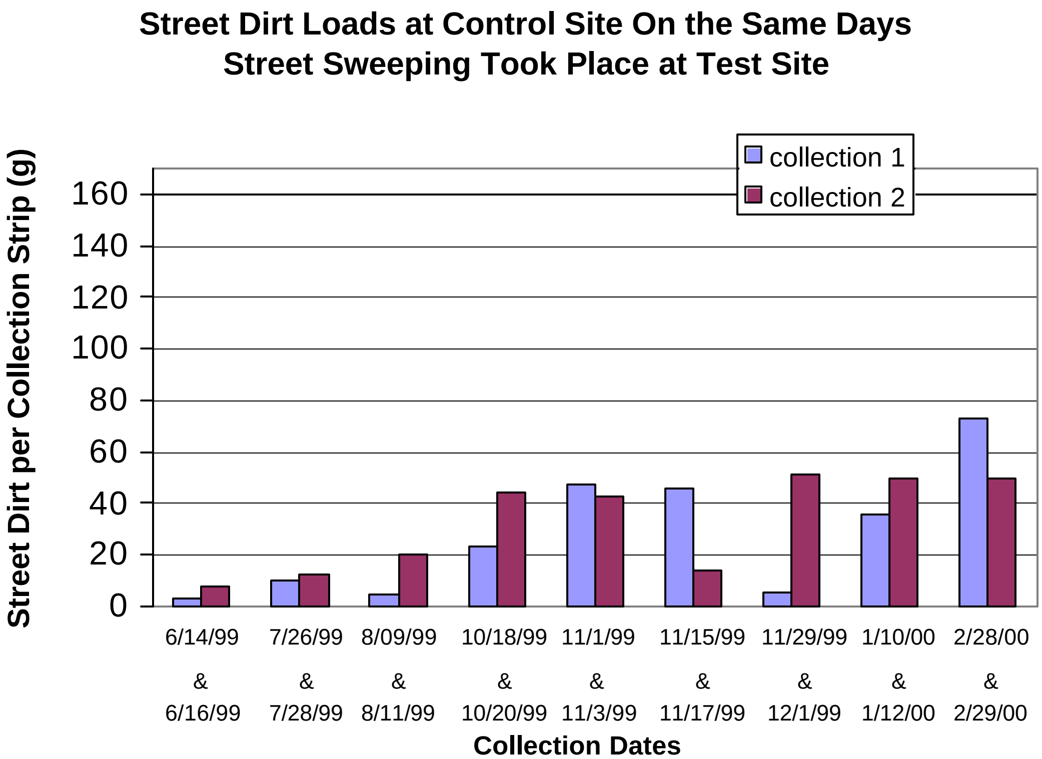


Figure 5. Highway Dirt Loads at Control Site on the Same Days Sweeping Occurred at the Test Site.

Table 3. Particle Size Distribution of Highway Dirt Collected by EnviroWhirl

Collection Date	**Percentage by Mass in Size Fractions**							
	>6.37 (mm)	**6.37-2.0 (mm)**	**2.0-1.0 (mm)**	**1.0-0.5 (mm)**	**0.5-0.25 (mm)**	**0.25-0.125 (mm)**	**0.125-.0625 (mm)**	**<0.0625 (mm)**
8/18/99	9.76	10.47	6.42	14.02	29.70	15.07	5.47	9.09

Table 4. Results of Toxicity Characteristic Leachate Procedure (TCLP) Analysis on Dirt Collected by EnviroWhirl Street Sweeper.

(mg/L., milligram per liter; Cd, cadmium; Ba, barium; As, arsenic; Cr, chromium, Pb, lead, Hg, mercury; Se, selenium; Ag, silver)

Collection Date	Total As (mg/L)	Total Ba (mg/L)	Total Cd (mg/L)	Total Cr (mg/L)	Total Pb (mg/L)	Total Hg (mg/L)	Total Se (mg/L)	Total Ag (mg/L)
8/18/99	Nd	0.62	0.02	Nd	0.09	Nd	Nd	<1.0
3/31/00	Nd	.30	Nd	Nd	Nd	Nd	Nd	<1.0
WDNR STANDARDS*	5.0	100	1.0	5.0	5.0	0.2	1.0	5.0
* SOURCE= WDNR ADMINISTRATIVE CODE, NR605.08, TABLE 1 (P. 27)								

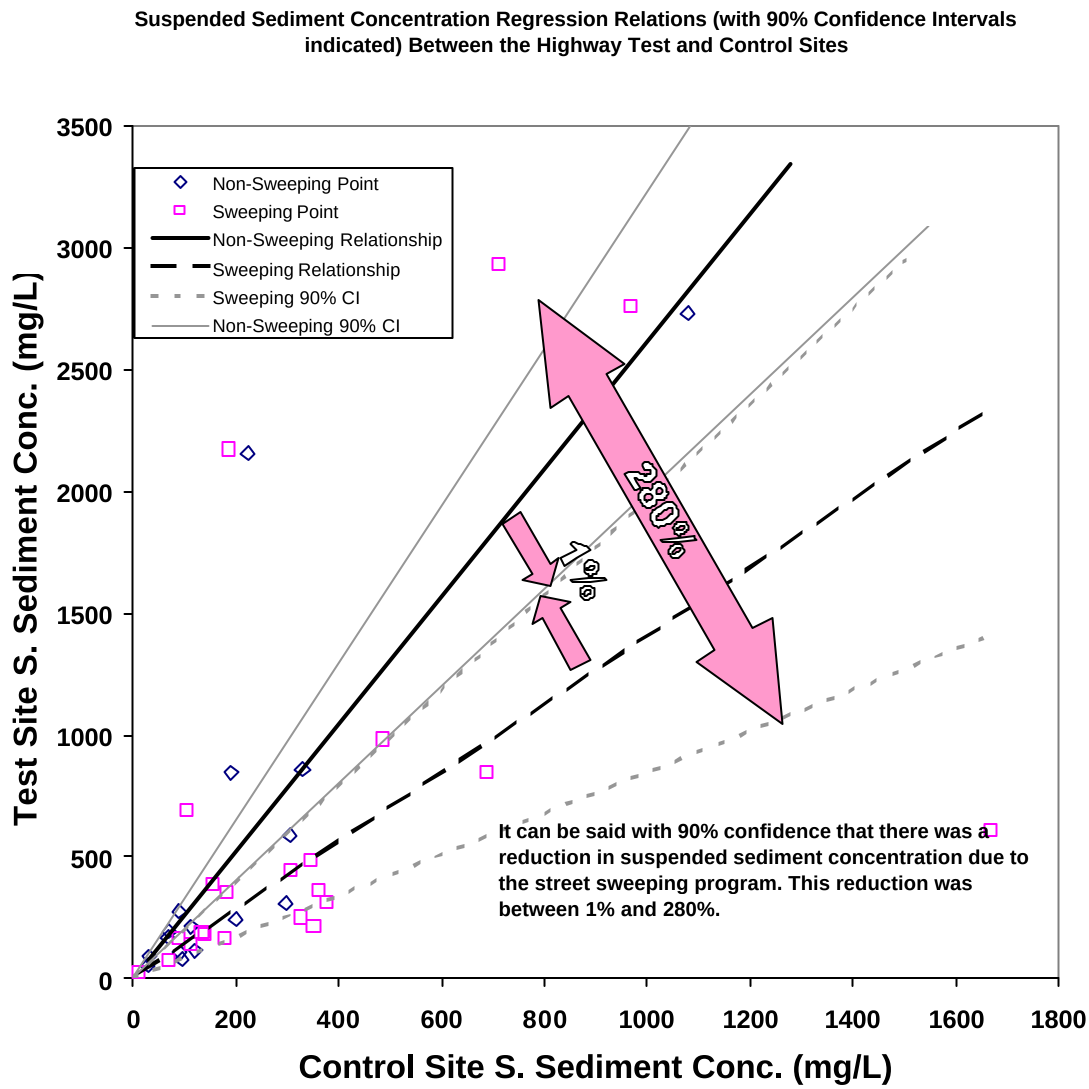


Figure 6. Suspended Sediment Concentration Regression Relations (at 80% Confidence Interval) Between Test and Control Sites

C. PRECIPITATION AND RUNOFF DATA FOR SAMPLED EVENTS

1. Precipitation Data for Sampled and Unsampled Events

Precipitation data for the entire period of the study including unsampled events are listed in Tables A5 and A6 (Appendix) These tables include starting and ending dates and time, total precipitation depth, maximum 15 and 30 minute intensities, Erosivity Index value and antecedent dry times.

2. Concentrations and Particle Size Data

Constituent concentrations and particle size data in runoff are in Tables A7, A8, and A9, (Appendix) Because of limitations in the number of data points for many of the constituents listed in Table 1 (page 6) the data analysis focused on suspended sediment.

3. Suspended Solids Versus Suspended Sediment

Figure 7 (page 16) shows that frequently the suspended sediment concentration result was significantly higher than the suspended solids result for the same event.

After viewing the data (Figure 7, page 16) and consulting the report by Gray and others (3), it was determined that the analysis for this study would use suspended sediment rather that suspended solids. The difference in the analysis methods between these two parameters may be particularly important when viewing roadway runoff data because of the prevalence of larger sized particles, which appear to accentuate the differences in results between the two analysis methods.

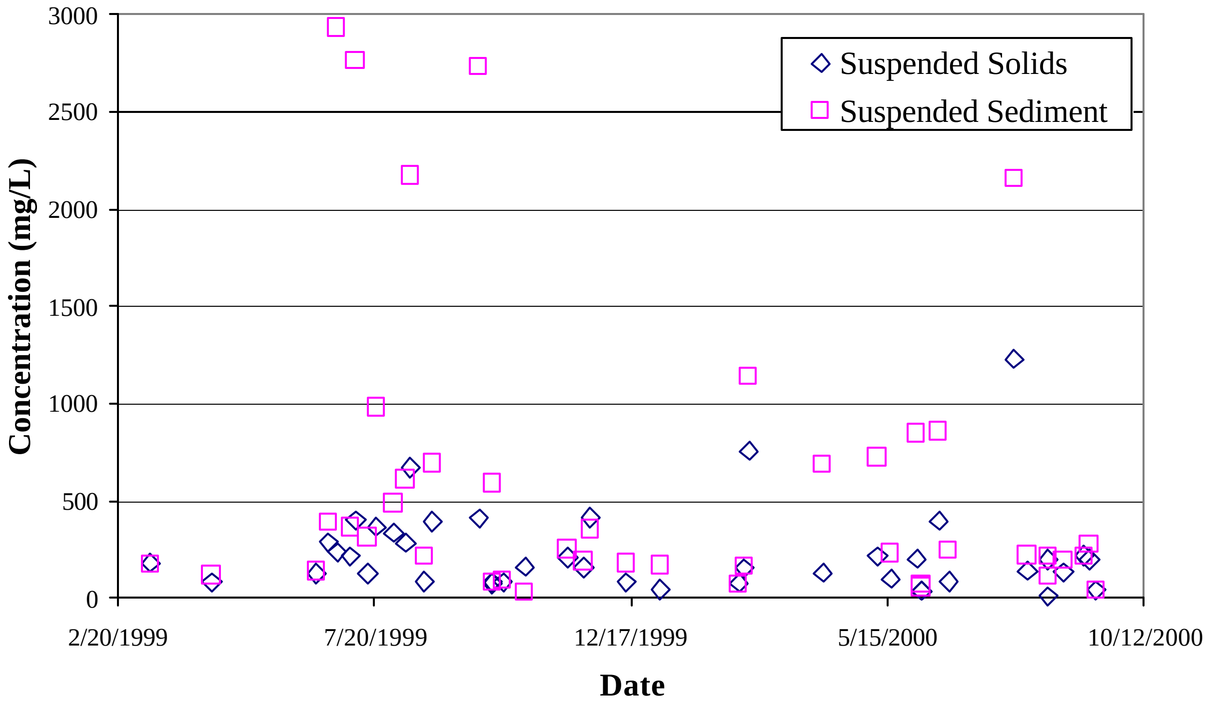


Figure 7. Suspended Solids Vs. Suspended Sediment at the Test Site.

4. Sediment Replicate Results

Thirty-two sediment replicate analyses were performed during the study. The average percent difference between these replicates was 46 percent with a standard deviation of 50 percent (Table 5, page. 18). These results are not encouraging. Two possible explanations for this variability are: (1) the churn splitter used to sub-sample the whole water sample into separate bottles for various analyses was not mixing the sediment sufficiently; or (2) the variability in the laboratory analyses. The USGS has done a series of tests on the churn splitter and found that it performs well as long as the concentration and particle size distribution in the water is within certain ranges (Horowitz and others, (4)). Specifically that the suspended sediment concentration is less than 1000 mg/L and the particle size is less than 250 um. Many of the samples from this study had particle sizes that exceeded the recommended particle size for the churn splitter and a few had concentrations in excess of 1,000 mg/L. These factors probably contributed to the problem; however, there were several samples where the particle size and concentration were within the churn splitters acceptable range yet the replicate results were poor. These results seem to indicate that there were probably some problems in the lab analysis as well. Complete QA/QC results are found in Tables 5, 6, and 7 (p.p. 18-21).

The amount of variability seen in the replicates (46 percent) makes all but the grossest changes in the runoff concentrations due to the sweeping program very difficult to detect.

Table 5. Suspended sediment replicate analysis results at the test and control sites

Test Site

Sample ID	Date	sample concentration (mg/L)	replicate concentration (mg/L)	% difference x
OK-26	11/19/1999	200	174.0	15%
OK-27	11/23/1999	351	356	1%
OK-28	12/14/1999	242.6	117	107%
OK-31	2/21/2000	162	161.8	0%
OK-32	2/24/2000	552	1137.5	51%
OK-33	4/7/2000	193	690.4	72%
OK-34	5/9/2000	989	722.4	37%
OK-35	5/17/2000	387	229.2	69%
OK-36	6/1/2000	1070	621.7	72%
OK-37	6/4/2000	74	37.1	99%
OK-41	8/5/2000	209	230.2	9%
OK-43	8/17/2000	169	51.0	231%
OK-44	8/26/2000	203.7	187	9%
OK-45	9/7/2000	192.0	234.0	18%
OK-46	9/10/2000	242.2	310.0	22%
OK-47	9/14/2000	34.7	42	17%
			mean	52%
			standard deviation	59%

Control Site

Sample ID	Date	sample concentration (mg/L)	replicate concentration (mg/L)	% difference
NT-25	11/10/1999	231	424.9	46%
NT-26	11/19/1999	109	162.4	33%
NT-27	11/23/1999	186	181	3%
NT-28	12/14/1999	178.8	106	69%
NT-30	2/18/2000	59	83.7	30%
NT-31	2/21/2000	91	93.7	3%
NT-33	4/7/2000	167	450.2	63%
NT-34	5/9/2000	152	97.1	57%
NT-35	5/17/2000	246	348.1	29%
NT-36	6/1/2000	165	215.3	23%
NT-37	6/4/2000	32	28.5	12%
NT-40	7/28/2000	325	122.3	166%
NT-43	8/17/2000	48	135.5	65%
NT-44	8/26/2000	73.3	68	8%
NT-46	9/10/2000	88.8	92	3%
NT-47	9/14/2000	62.7	48	31%
			mean	40%
			standard deviation	41%

overall mean	46%
overall standard deviation	50%

Table 5. Replicate Suspended Sediment Analysis Results at Test and Control Sites.

Table 6. Suspended solids replicate analysis results at the test and control sites

Test Site

Sample ID	Date	sample concentration (mg/L)	replicate concentration (mg/L)	% difference
OK-12	7/9/1999	230	569	147%
OK-13	7/16/1999	159	98	38%
OK-31	2/21/2000	154	152	1%
OK-33	4/7/2000	113	150	33%
OK-34	5/9/2000	185	244	32%
OK-44	8/26/2000	134	65	51%
OK-45	9/7/2000	245	193	21%
OK-46	9/10/2000	115	280	143%
			mean	58%
			standard deviation	56%

Control Site

Sample ID	Date	sample concentration (mg/L)	replicate concentration (mg/L)	% difference
NT-12	7/9/1999	232	145	38%
NT-13	7/16/1999	106	131	24%
NT-31	2/21/2000	90	84	7%
NT-33	4/7/2000	112	126	13%
NT-34	5/9/2000	108	124	15%
NT-44	8/26/2000	62	120	94%
NT-46	9/10/2000	69	73	6%
			mean	28%
			standard deviation	31%

overall mean	44%
overall standard deviation	47%

Table 6. Replicate Analysis Suspended Solids Results at the Test and Control Sites.

Table 7. Blank sample analysis results at the test and control sites.

Test site

Sample ID	QOK-12	QOK-13	QOK-23	QOK-24	QOK-33	QOK-34	QOK43	QOK-44	
Type of sample	splitter blank	filter blank	splitter blank	filter blank	splitter blank	filter blank	splitter blank	filter blank	lowest environmental concentration
Date	6/3/99	6/3/99	9/30/99	9/30/99	4/13/00	4/13/00	9/21/00	9/21/00	
Constituent									
COD (mg/L)	nd	--	nd	--	nd	--	nd	--	36
Total Solids (mg/L)	nd	--	nd	--	nd	--	nd	--	204
TSS (mg/L)	nd	--	nd	--	nd	--	nd	--	9.5
Diss. NH3 (mg/L)	nd	--	nd	--	nd	--	nd	--	0.249
Total NH3 + organic N (mg/L)	nd	--	nd	--	nd	--	nd	--	0.71
Diss. NO2+NO3 (mg/L)	nd	--	0.01	--	nd	--	nd	--	0.309
Total P (mg/L)	nd	--	nd	--	nd	--	0.009	--	0.092
Diss. Ortho-P (mg/L)	--	0.002	--	nd	--	nd	--	nd	0.006
Total Ca (mg/L)	0.06	--	0.06	--	0.05	--	0.02	--	20
Total Mg (mg/L)	0.06	--	nd	--	nd	--	nd	--	9
Diss. Cl (mg/L)	0.2	--	0.5	--	0.8	--	nd	--	7.2
Diss. Cu (ug/L)	--	nd	--	1.4	--	nd	--	nd	5.8
Diss Zn (ug/L)	--	nd	--	nd	--	nd	--	nd	12
Total Zn (ug/L)	nd	--	nd	--	nd	--	nd	--	80
Total Cd (ug/L)	0.04	--	nd	--	0.05	--	nd	--	0.48
Total Pb (ug/L)	nd	--	nd	--	nd	--	nd	--	18
Total Cu (ug/L)	nd	--	nd	--	nd	--	nd	--	25
Total Hardness (mg/L)	0.4	--	0.3	--	0.2	--	nd	--	87

Control site

Sample ID	QNT-12	QNT-13	QNT-23	QNT-24	QNT-31	QNT-32	QNT-33	QNT-34	QNT-35	QNT-43	QNT-44	
Type of sample	splitter blank	filter blank	splitter blank	filter blank	before blank	ISCO blank	splitter blank	filter blank	after blank	splitter blank	filter blank	
Date	6/3/99	6/3/99	9/30/99	9/30/99	4/13/00	4/13/00	4/13/00	4/13/00	4/13/00	9/21/00	9/21/00	lowest environmental concentration
COD (mg/L)	nd	--	nd	--	nd	nd	nd	--	nd	nd	--	41
Total Solids (mg/L)	nd	--	nd	--	nd	nd	16	--	nd	10	--	130
TSS (mg/L)	nd	--	nd	--	nd	nd	6	--	nd	nd	--	11
Diss. NH3 (mg/L)	nd	--	nd	--	nd	nd	nd	--	0.016	nd	--	0.026
Total NH3 + organic N (mg/L)	nd	--	nd	--	nd	nd	nd	--	nd	nd	--	0.33
Diss. NO2+NO3 (mg/L)	nd	--	0.003	--	nd	nd	0.017	--	nd	nd	--	0.299
Total P (mg/L)	nd	--	nd	--	0.002	0.003	0.006	--	0.003	0.012	--	0.102
Diss. Ortho-P (mg/L)	--	0.003	--	nd	--	--	--	nd	--	--	nd	0.004
Total Ca (mg/L)	0.06	--	0.04	--	nd	0.16	0.71	--	0.16	0.04	--	13
Total Mg (mg/L)	nd	--	nd	--	nd	0.03	0.31	--	nd	nd	--	5.3
Diss. Cl (mg/L)	nd	--	nd	--	nd	4.8	5.1	--	nd	nd	--	9.4
Diss. Cu (ug/L)	--	nd	--	nd	--	--	--	nd	--	--	nd	7
Diss Zn (ug/L)	--	nd	--	nd	--	--	--	nd	--	--	nd	18
Total Zn (ug/L)	nd	--	nd	--	nd	nd	220	--	nd	nd	--	63
Total Cd (ug/L)	nd	--	nd	--	nd	nd	0.05	--	nd	nd	--	0.45
Total Pb (ug/L)	nd	--	nd	--	0.9	nd	3.2	--	1.1	nd	--	19
Total Cu (ug/L)	nd	--	nd	--	1	nd	1	--	nd	1	--	20
Total Hardness (mg/L)	0.2	--	nd	--	nd	0.5	3.1	--	nd	nd	--	55

nd, not detected
--, not analyzed for

shaded data indicates an unacceptably high concentration

5. Traffic Count Data

In general, vehicle count data during runoff events between the sites were close. Ninety percent of the counts were within 46 percent of each other, 80 percent were within 31 percent, 75 percent were within 26 percent and 50 percent were within 8 percent of each other. Where large differences were measured, they may be attributable to construction and maintenance activities, which while not occurring in the study area may have been on sections of freeway near enough to alter traffic patterns within the study area. Vehicle count data are found in Table A10 (Appendix).

6. Median Runoff Contribution

The median comprised 1.8 percent of the drainage area in the test basin and 1.0 percent in the control basin. In an attempt to determine the affect of the median area runoff contribution on the study results, sampling equipment (Refer to Appendix for photos of sampling equipment) was installed at one of the median inlets attached to the freeway drainage system. The sampling equipment was designed to collect a runoff sample from the test section median whenever a sample was collected at the test section outlet sampling point (Frequently, the median sampler did not collect a water sample when it was triggered to do so. It was assumed that this was due to the fact that no runoff was produced in the median area for that event). The data collected from this sample point was used to determine an estimate of the effect of the median area on the study results (These are approximate calculations. The actual values are not as important as the concept that they are intended to illustrate). The suspended solids concentration results of samples collected in the median area are listed in Table 8.

Table 8. Suspended Solids Concentrations Found in Runoff Samples Collected from the Freeway Median

Test site median

Field ID	Collection start date and time	Collection end date and time	Event Number	Sub-sample number	TSS (mg/L)
OKM-1	7/27/00 4:41	7/27/00 4:44	-	1-3	1480
OKM-2	7/27/00 4:45	7/27/00 4:49	-	4-6	998
OKM-3	7/28/00 12:29	7/28/0012:32	40	1-2	4232
OKM-4	7/28/00 12:44	-	40	3	7270
OKM-5	7/28/00 12:46	7/28/0012:48	40	4-5	1060
OKM-6	8/17/00 4:19	8/17/00 7:34	42	1,5,6,23	678
OKM-7	8/26/00 10:09	8/26/0010:17	44	1-2	1580
OKM-8	9/10/00 8:04	9/10/00 8:15	46	1-3	1730
OKM-9	9/14/00 1:48	-	47	1	515
OKM-10	9/14/00 1:57	-	47	2	5140
OKM-11	9/22/00 12:57	9/22/0014:00	-	12-20, 24	207

The total suspended solids concentration in the median runoff ranged from three to seventy-one times higher than the concentrations of the samples at the test section outlet sampling point. The average for the median total suspended solids data was between six to twenty times higher, depending on how the calculations were done, than the data at the test section outlet.

7. Sweeper Operation Diary

The sweeper operator maintained a sweeping diary from May 11, 1999 through March 15, 2000. The following information was recorded for each sweeping operation:

- Date and Time
- Weather Conditions
- Pavement Conditions
- Hours of Operation
- Observations
- Amount of Material Collected

The sweeper operation diary form is included in the Appendix. The planned sweeping schedule and the actual number of sweeping operations were as follows:

Year	Month	Number of Sweeping Operations		
		Original Plan	**Revised Plan**	**Actual**
1999	May	2	2	3
	June	4	5	5
	July	4	5	3
	August	0	4	3
	September	0	0	0
	October	4	6	4
	November	4	5	4
	December	1	2	4
2000	January	2	2	3
	February	2	0	3
	March	4	2	3
	Total	27	33	35

IV. DATA ISSUES DISCUSSION

A number of issues related to the study conditions may have affected the data collected and the variability of the data confidence interval. It is difficult to determine which of these issues had the most affect on the confidence level of the collected data. The following three items most likely had the most influence on the confidence level calculation in the order that they are listed.

A. Poor Reproducibility in Suspended Sediment Replicate Analyses

The mean percent difference in replicate suspended sediment analyses was 46 percent with a standard deviation of 50 percent. These results are presented in Table 5 (page 18). The particle size data from these sites indicate that the highway runoff has larger particles than those seen in nearly all other USGS monitoring sites. These larger particle sizes probably contributed to the data results. When variability found in replicate samples are that high, detecting comparatively minor reductions in suspended sediment concentrations is very difficult.

B. Median Contribution

The median comprised 1.8 percent of the drainage area in the test basin and 1.0 percent in the control basin. The medians were not maintained in any way, contained several inches of dirt, and had several inlets to the storm drainage system in them.

C. Limited Number of Data Points

This study lost some data points because of some unexpected utility construction in the grassy right-of-way areas in the study area that began on May 1, 1999. Runoff concentration and highway dirt data collected from that date until about June 10, 1999 appeared high and were not used in the analysis. The small sampling size and mostly impervious area of the test and control sites made collection of acceptable runoff samples difficult due to the rapidness of hydrograph response to rainfall. This difficulty further reduced the number of data points available for analysis.

The following four items may have had a secondary influence on the confidence level calculation.

D. Limitations on Areas Swept

Because of the slow operational speed of the EnviroWhirl sweeper, only the shoulders and not the traffic lanes could be swept. In addition, it was necessary to use a truck and trailer to get the sweeper to the inside shoulder of the freeway safely. Since this operation was cumbersome, the inside shoulder was swept with the EnviroWhirl only every other week. On the alternate weeks, the inner shoulder was swept with a mechanical sweeper currently being used by Milwaukee County. As a result of this schedule, every other week only half of the potentially treatable highway surface was swept with the EnviroWhirl unit.

The active traffic lanes in the test section were not swept or sampled due to high traffic volumes and safety concerns. Previous studies (11,12) have indicated that the majority of the dirt accumulated in the live traffic lanes is moved to the shoulder lanes by the movement of traffic in the live lanes. Photos of the EnviroWhirl unit in use included in the Appendix show the accumulation of this dirt in the shoulder lane.

E. Possible Sweeper Problems

At the end of the study in April, 2000, there were some questions regarding the condition of the EnviroWhirl sweeper. Apparently some brushes were on incorrectly and some of the filters were not working properly. At a meeting of the participating parties, it was decided that most likely these problems occurred after the conclusion of the study. From direct observations of the sweeper performance, it did not seem to be performing as well as expected. Dirt piles and debris were noted on surfaces immediately after the sweeper had passed over them. Whether this performance was to be expected or was due to the poor pavement condition, dirt type, dirt location, sweeper problems or some other reason(s) is undetermined.

Another issue related to the sweeper operation that may have affected the results was the operator's familiarity with the unit and his comfort level and skill in operating the sweeper.

F. Utility Construction Within Study Area

Utility trenching and restoration through the study area occurring from early May, 1999 through June, 1999 affected the data collected during this period. The questionable data was eliminated from the final analysis.

G. Variation Between Test Area and Control Area Impervious Surface

The difference in the percentage of impervious surface between the test basin (95% impervious) and the control basin (63% impervious) probably contributed to the difference in the percent runoff between the test site (mean % runoff= 62%) and the control site (mean % runoff = 28%).

Researchers performing similar sweeping studies in the future should take these issues into consideration when the studies are being designed.

V. Sweeper Operations And Maintenance Issues

Milwaukee County Department of Public Works staff that operated the EnviroWhirl EV2 sweeper and supervised the operation provided the following comments on the operation and maintenance of the unit. It should be mentioned that the smaller EnviroWhirl II unit that was used for this study was designed to be used in parking lots and on local streets instead of on freeway shoulder locations. The larger EnviroWhirl model, that was not available for this study, would have been more appropriate. Many of the following comments made by Milwaukee County personnel would have been issues to be addressed no matter what manufacturer or model of sweeper was used in this situation. As the study progressed, it is possible that the sweeper operator adjusted to the equipment and his skill in operating the sweeper improved such that driver decisions were less of an influence on the variability of the data collected.

Equipment Operation:

(1) The travel speed of the unit (12 M.P.H.) is too slow to be self-driven on the freeway. The unit had to be transported on a flat bed trailer increasing the cost of the operation;
(2) The operational speed of the unit (5 m.p.h.) required the need for a trailing, “blocking” truck on the freeway to protect the sweeper unit, further adding to the cost of the operation;
(3) Operator was unable to drive unit across live traffic lanes from the shoulder lane to the median, distress lane due to the travel speed of the unit. Sweeper had to be transported on a flat bed trailer to be moved across the freeway lanes;
(4) No operational break downs occurred while sweeping the test area;
(5) The operator was uncomfortable seated in the sweeper cab due to a lack of an air supported, cushioned, suspension seat;
(6) The operator’s visibility behind the unit was not acceptable. The rear mounted viewing camera offered little help due to the poor quality image when sun shined on the monitor screen;
(7) Need better access to clean out/inspection plate under the cab. The current access is hard to reach and not large enough to be able to reach into and remove clogged material;
(8) Unit swept well on dry, flat pavement surface. Wet pavement caused by rain, snow, or slush prevented unit from operating as efficiently as on dry pavement;
(9) Damp material clogged up suction tube and filters. Unit needs an air scrubber to keep the tube clean;
(10) Sweeping results over shoulder rubble strips, cracked pavement, or raised pavement sections was not as effective as on flat pavement areas;
(11) No indicator in the cab to indicate the air flow status in the pick-up tube to assist with the indication of clogging in the tube;
(12) Four wheel steering works well for straight ahead steering but unit is difficult to turn around obstacles or curbs;
(13) Sweeper brooms:
   (a) Main broom diameter is not large enough,
   (b) Increased down pressure on front wheels is not possible,
   (c) Gutter broom can only be adjusted manually with a wrench. As the broom wears, adjustment is needed by manually lowering the broom. Adjustment can not be done by the operator from the cab,
   (d) Need greater downward pressure adjustment on the brooms to be able to sweep both along median barrier and within gutter ditch effectively,
   (e) Pick up broom width would have to wider to be able to sweep in tandem with other mechanical sweeper,

(f) Brooms will not “float” into depressions in the pavement or along the gutter ditch area. would not adjust to irregular surfaces due to fixed position of brooms,
(g) On occasion, gutter broom would throw material into the live traffic lanes instead of into the area where material could be picked up by the main broom,
(h) Width of the sweeping coverage was not adequate. Would need to either use both gutter brooms together or double sweep the area (within “break down” lane).

(14) No noticeable amount of dust was released to the air during the sweeping operation;
(15) Could not pick up larger materials (such as sticks, debris, large rocks) as well as current mechanical sweepers. Would have to work in tandem with another sweeper that picked up larger material;
(16) Clean out of debris from the collection box was difficult
(17) Some jamming of the auger due to material picked up that was larger than an “egg”.
(18) Sweeper was used in the County yard and shop areas to clean parking surfaces and floors when the field study was completed and the unit performed well in those locations.

Equipment Maintenance:

(1) Very few equipment maintenance issues had to be addressed;

(2) No downtime for repairs when the sweeper unit was operating on the test section;

(3) Sweeper brooms did not have to be replaced during the course of the study;

(4) Material conveyor system became jammed once and needed repair;

(5) Not much preventative maintenance, such as greasing, is needed.

VI. SIMPTM Modeling

The study work plan called for the data collected during the study period to be used for the recalibration of the Simple Particulate Transport Model (SIMPTM). Due to the reassignment of study personnel and the lack of trained staff within WisDOT familiar with the SIMPTM model, this study task was not completed. It is possible that when personnel and work schedules allow, that this task will be carried out by the WisDOT environmental staff.

VII. Discussion

A. Highway Dirt

Figure 4 (page 11) indicates that pavement sweeping in the test section did decrease the highway dirt loading during 7 of the 9 sweeping events. Figure 5 (page 12) shows the pavement dirt load at the control site on the same days as samples were collected in the test site. At the control site no sweeping occurred between these collections and the pavement dirt load increased for six of the nine events. Although this was an insufficient amount of data for statistical testing, it did seem to indicate that the sweeping operation was reducing the pavement dirt load.

Data in Table 3 (page 12) on the particle size of the material collected is presented for informational purpose only. No analysis or comparison to other data was attempted. Since only one sample of dirt was collected from the sweeper, it is difficult to reach any conclusions on this data. Data could be compared to that presented in Table A3 (Appendix) from the test site.

The TCLP analysis performed on two samples of dirt collected from the sweeper (Table 4, page 13) indicated results that were below levels specified in WDNR Administrative Code NR605.08

Table 7. Summary statistics for event mean concentrations of constituents with detection frequencies of at least 10 percent at Wisconsin storm-sewer-monitoring sites

[CV, coefficient of variation; mg/L, milligrams per liter; µg/L, micrograms per liter; mL, milliliter; <, less than]

Constituent	Minimum reporting limits	Number of samples	Maximum	Minimum	Median[1]	Mean	CV
		Conventional constituents (mg/L, unless otherwise noted)					
pH (standard units)	0.1	131	8.11	5.63	7.3	7.24	0.0579
Chemical oxygen demand, COD	5	97	310	<5	48	69	.86
BOD, 5-day at 20°C	1	112	210	<1	9.4	18	1.5
Coliform, fecal (colonies/100 mL)	10	54	370,000	<10	6,500	30,000	2.3
Hardness, dissolved	6	173	220	<6	26	33	.79
Hardness, total	6	209	900	3	51	87	1.3
Alkalinity, total as $CaCo_3$	.5–1	82	149	2	34.5	40.7	.66
Sulfate, dissolved	1	26	23	<1	9	9.1	.67
Chloride, dissolved	.01–1	94	1,000	<.01	10	64	2.5
Suspended solids	2	247	1,850	<2	120	237	1.31
Total solids	10	167	2,810	<10	256	386	1.06
Nitrite plus nitrate, dissolved	.01	147	73.6	<.01	.493	1.1	5.5
Nitrogen, ammonia, dissolved	.005–.01	102	1.3	<.01	.24	.3	.83
Nitrogen, ammonia, organic, total	.2	34	34	<.2	1	1.8	1.9
Phosphorus, total	.01–.02	204	3.8	<.02	.29	.45	.49
Phosphate, ortho, dissolved	.002	137	3.31	<.002	.09	.178	1.93
Carbon, organic total	.5	100	66	<.5	11	16	.89
		Metals and inorganics (µg/L)					
Antimony, total recoverable	1–5	74	4	<1	<1	1.2	.6
Arsenic, total recoverable	1–10	71	5	<1	1	1.1	.9
Cadmium, total recoverable	.2–1	197	7	<.2	.5	.89	1
Cadmium, dissolved	.2	89	3.8	<.2	.08	.3	2
Chromium, total recoverable	1–3	164	90	<3	7	11	1.1
Copper, total recoverable	1–3	223	210	<3	18	26	.96
Copper, dissolved	1–3	120	33	<3	5	6.5	.9
Cyanide, total	.01	59	.09	<.01	<.01	.005	2.5
Lead, total recoverable	1–3	230	570	<1	24	48	1.4
Lead, dissolved	1–3	120	13	<1	<3	.87	1.8
Nickel, total recoverable	1–10	81	52	<1	5	8.3	1.1
Silver, total recoverable	.5–5	129	52	<.5	<.5	1.9	3.6
Zinc, total recoverable	10	249	1,500	<10	150	200	.86
Zinc, dissolved	10	135	840	<10	70	89	1

B. Concentration and Particle Size

Data in Tables A7 and A8 (Appendix) are results from individual runoff events and were used to develop the data presented in Table 2 (page 7)

Data in Table 2 (page 7) was compared to similar runoff data collected from previous storm water studies in Wisconsin (Table 7, page 13, "Quality of Wisconsin Storm water, 1989-1994, U.S. Geological Survey File Report 96-458) shown on page 32. Visual inspection of the data indicated similar results for the concentrations of constituents tested for during this study.

Data presented in Table A9 (Appendix), "Runoff Particle Size Analysis Results at the Test and Control Sites", indicated much larger size particles than have normally been observed in other USGS storm water runoff studies where almost the entire sample size was below 0.062 mm. Samples collected during this study may have been influenced by the material accumulated in the median area, by the type of vehicles (trucks hauling granular material) using this section of freeway, winter sand use, pavement surface wear, or other factors on the freeway system.

C. Replicate Analyze

Replicate analyses were performed on samples collected during the study (Tables 5 and 6, p.p. 18-19) for Total Suspended Sediment and Total Suspended Solids values. Changes in the way samples were collected and processed from earlier studies may have affected the results obtained from these samples. The average percent difference between the replicate samples and the standard deviation of the samples were larger than what would be expected. Refer to Section III.C.4 (page 17) for further discussion on the explanations for the variability of the results. How the samples were collected and split may have affected the variability of the study results.

D. Suspended Solids and Suspended Sediment

After reviewing the difference in Total Suspended Solids (TSS) and Total Suspended Sediment (S.Sed.) data (Table 2, page 7 and Figure 7, page 16), it was decided to only use Total Suspended Sediment data in the analysis. Differences in the data results may have been due to the differences in the methods used to analyze the constituents. It was concluded that Total Suspended Sediment data more accurately reflected typical highway storm water runoff than TSS.

A statistical comparison of Total Suspended Sediment levels in the test and control section runoff indicated between a 1-280% reduction in the Total Suspended Sediment concentration due to the weekly sweeping schedule at the 90% confidence interval (Figure 6, page 14).

E. Blank Sample Results

The blank sample analysis (Table 7, page 20) indicted that there was not any extreme amount of contamination contained in the samples collected. Only one sample, total zinc, produced a level that would be considered much higher that what would be expected. The remainder of the samples were at the acceptable level. These results would seem to indicate that the sampling technique used was acceptable.

F. Traffic Counts

Traffic count data, (Table A10, Appendix) was collected for the test and control area with the intent of entering the data in the SIMPTM model. Refer to Section VI. SIMPTM Modeling (page 30) for additional discussion. No statistical analysis of the traffic count data was performed.

G. Median Runoff Contribution

Suspended solids concentrations found in runoff samples collected from the median area of the test section indicated much higher levels than those from samples collected from the test section pavement. Values of eleven samples averaged 2,260 mg/ liter and ranged from 207-7,270 mg/liter for total suspended solids in the median area (Table 8, page 25) while values of 41 samples averaged 235 mg/liter in the test section (Table 2, page 7). While it may appear that the influence of material present in the median area could very likely have influenced the results of data collected from the test section and directly masked the effectiveness of the high efficiency sweeper results, the affect on the study data from the drastically higher concentrations may not be as profound as it appears due to the following two factors:

(1) The drainage area within the test section median only made up 1.8% of the total drainage basin area of the test section, and

(2) Precipitation falling on the median area was less likely to produce runoff than precipitation falling on the pavement area since the median area was a permeable gravel surface allowing for some infiltration.

Upon inspection of the median area runoff data, it appears that it took a precipitation event with an erosivity index (EI) greater than 1.0 to trigger the median sampler. For the length of the study, 47 of 131 events (35%) had an EI of greater than or equal to 1.0. Those events accounted for 80% of the total precipitation during the study period. Within the 35% of the events that likely produced median runoff, it is likely that runoff from the median occurred less than 50% of the time. For a worst case scenario (EI greater than 1.0, 71times higher concentration of TSS, and runoff during 50% of the events), the TSS contribution from the median was calculated to be 33% of the total basin loading for TSS. For a best case scenario (EI greater than 1.0, 3 times higher concentration of TSS, and runoff during 15% of the events), the TSS contribution from the median was calculated to be 0.4 % of the total basin loading for TSS. For a realistic case scenario (EI greater than 1.0, 10 times higher concentration of TSS, and runoff during 30% of the events), the TSS contribution from the median was calculated to be 2.3% of the total basin loading for TSS.

H. Sweeper Operation

Since the EnviroWhirl sweeper that was provided to Milwaukee County for this study was new to the operators that were assigned to the sweeper, it was possible that as the study progressed, the operators became more familiar with its operation and their skill level when operating the sweeper may have increased while the influence of driver decision errors on the variability of the data decreased. The data collected during the course of the study was not analyzed for the possibility of this occurring. The sweeper unit used for this study was not designed for freeway operations. This factor may have influenced how the sweeper performed and also the operator's comments on the operation of the unit.

VII. CONCLUSIONS

Based on the data collected and analyzed during this study, the following conclusions were reached:

(6) Highway storm water runoff—sweeping operations performed once per week with the EnviroWhirl EV2 sweeper in the test section decreased the freeway pavement dirt loading. The study showed that at the 90% confidence interval there was a reduction in the total suspended sediment concentration of runoff due to the sweeping program. Statistically the reduction was in the range of 1-280%. A once a per week freeway sweeping program may be an effective storm water runoff best management practice (BMP) for urban freeway highways.

(2) Toxicity characteristic leachate procedure (TCLP) analysis of highway dirt samples—testing performed on dirt collected by the sweeper indicated that pollutant concentration levels of the material collected did not exceed standards. The collected material should not require any special disposal restrictions.

(3) Particle size in highway water runoff—samples collected during the study exhibited larger particle size distributions than have been observed in other land use runoff studies. Samples collected may have been influenced by (1) attempts during the study to collect larger sized particles, (2) factors related to the freeway system such as types of vehicles using the freeway and the materials being hauled, winter season sand use, pavement surface wear, or the contribution to the runoff from the confined median area. This finding raises the possibility that previous storm water runoff studies may have under-estimated the effectiveness of highway sweeping programs.

(4) Suspended sediment replicates—the amount of variability observed in the analyzes make all but the grossest changes in the runoff concentrations due to the sweeping program very difficult to detect.

(5) Suspended sediment concentrations—data for suspended sediment seems to more accurately reflect the characteristics of highway storm water runoff than the total suspended solid concentration data collected.

(6) Quality control testing—seems to indicate that the field sampling techniques used for this study were reliable. However, variability in laboratory sampling and analysis may have influenced the laboratory test results.

(7) Influence of material present in the confined median area--may have influenced the laboratory data for the samples collected in the test section and could have possible masked the effectiveness of the sweeping study results.

(8) Sweeper operational issues—many issues with the high efficiency sweeper encountered during the study, such as the travel speed of the unit, the need for a following traffic control vehicle, insufficient pick up of material on uneven surfaces, and the lack of flexibility of the gutter brush, may make the use of this particular model on high speed freeway sections unreasonable with its current configuration.

IX. RECOMMENDATIONS

Based on the data presented in the study and the conclusions arrived at from the analysis of the data, the following recommendations are presented:

(1) The Wisconsin Department of Transportation (WisDOT) should consider:

(a) requesting that sweeper manufacturers develop a high efficiency sweeper mounted on a truck chassis capable of travels speeds of 50-55 m.p.h. and higher operational speeds than the current models without affecting the performance of the sweeping operation.

(b) require that urban county highway departments purchase and use high efficiency sweepers in conjunction with existing mechanical sweepers on urban freeway sections. Joint use of a high efficiency sweeper by adjacent counties should also be encouraged. Provide specific guidelines on freeway sweeping in the WisDOT Maintenance Manual.

(c) establish a sweeping program to control storm water runoff pollutant concentrations.

(d) use data collected during this study in existing computer model programs. Data entry and analysis could be performed by the WisDOT Bureau of Environment.

(2) Perform additional field sweeper testing, data collection, and modeling that will measure the efficiency level of an one time per two week sweeping schedule to minimize storm water runoff pollutant concentrations. Other variables to be considered include the influence of traffic volumes, traffic speed, and highway design on pollutant loading in the test section. The influence of enclosed median area pollutant's accumulation on the data collected also needs to be explored.

(3) Develop maintenance manual guidelines for the sweeping of urban freeway sections for the control of storm water runoff pollutant concentrations. Include guidelines on spring season sweeping schedule, summer and fall season sweeping schedule, tandem sweeping using mechanical and high-efficiency sweepers, and single sweeper operations.

(4) Install a trap system within the confined median areas of the freeway system to prevent storm water runoff materials from those areas to leave the median via the storm water collection system. Develop a clean out program and schedule to collect and dispose of the materials trapped in the median area. Perform additional laboratory testing and analysis of material collected from the confined median area on the freeway system.

(5) Discuss with the Wisconsin Department of Natural Resources the results of this study and the acceptance of a high efficiency sweeper program as an effective best management practice (BMP) for storm water runoff control on urban freeway sections. Modify existing WDOT/WDNR Memorandum of Understanding to include specific information on freeway sweeping as a BMP.

(6) Discuss the results of study with the WisDOT Bureau of Environment to determine how the results relate to Trans 401 requirements and the TSS requirements to be accomplished by 2013.

REFERENCES

(1). Pitt, R., 1979, Demonstration of Nonpoint Pollution Abatement through Improved street and Sewerage Cleaning: U.S. Environmental Protection Agency, Cincinnati, Ohio, Report No. EPA-600/2-79-161, Aug. 1979.

(2). Bannerman, R.T., Baun, K., Bohn, M, Hughes, P.E., and Graczyk, D.A. 1983, Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin, Volume I, Urban Storm Water Characteristics, Pollutant Sources, and Management by Street Sweeping: U.S. Environmental Protection Agency, Water Planning Division, PB-84-114164. 191 p.

(3). Gray, J.R., Glysson, D.G., Turcois, L.M., and Schwarz, G.E., 2000, Comparability of Suspended Sediment Concentration and Total Suspended Solids Data: U.S. Geological Water-Resources Investigation Report 00-4191, 20 p.

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(5). National Highway Runoff Water Quality Date and Methodology Synthesis www.rvares.er.usgs.gov/osw/fhwa, May 19, 1997.

(6). Evaluation and Management of Highway Runoff Water Quality, FHWA Publication No. FHWA-PD-96-032, June 1996.

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(8). Storm water Treatment BMP Evaluation, Port of Seattle, WA., Kurahashi & Associates, Inc., March 1997.

(9). Best Practices: Street Sweeping, Metropolitan Council, St. Paul, MN., April 1994.

(10). Sutherland, Roger, March, 1999, Water Quality Benefits of High Efficiency Street Sweeping, Pacific Water Resources.

(11). Pitt, Robert, August, 1979, Demonstration of Non Point Pollution Abatement Through Improved Street Cleaning Practices, Environmental Protection Agency, Report EPA-600/2-79-161.

(12). Sheehan, D.J., March, 1975, Contribution of Urban Roadway Usage to Water Pollution, Environmental Protection Agency, EPA-600/2-75-004.

APPENDIX

1. Research Project Proposal Form for “Pollutant Loadings to Storm Water Run-off from Highways: The Impact of a Sweeping Program “Study, January, 1966

2. Excerpts from “Memorandum of Understanding By and Between the WDNR and the WisDOT Relating to the Authorization of Storm Water Discharges to Waters of the State of Wisconsin, Attachment A4”, January 26, 1999.

3. WisDOT Street Sweeping Evaluation Work Plan, March 10, 1999.

4. Study Location Map.

5. Test and Control Section Map and Photos.

6. EnviroWhirl EV2 High Efficiency Sweeper, Product Literature.

7. EnviroWhirl EV2 Photos.

8. Field Sampling Equipment Photos.

9. Field Sampling Plan.

10. Street Sweeping Operator’s Diary Form

11. Study Time Line.

12. Data Tables A1-A10

0092-45-80

Wisconsin Department of Transportation
FY 1997 RESEARCH PROJECT PROPOSAL FORM

Research project submittals for FY 1997 must be completed on this form. No additional attachments will be accepted. Incomplete forms will be returned. See the "Instruction Sheet" for further detail. Proposed project submittals are due ***January 15, 1996.***

I. PROBLEM TITLE:

Pollutant Loadings to Storm Water Run-Off from Highways: The Impact of a Sweeping Program

II. BACKGROUND AND PROBLEM STATEMENT:

Because of new Department of Natural Resources and coastal water regulations, the Department is responsible for controlling the water quality of run-off from state highways. One approach to improving the water quality is the routine sweeping of pavements. The material would then be disposed so that it does not enter the storm water discharge system. This study would determine the effect of various different frequencies and types of collection (power broom, sweep-all, vacuum) on water quality.

III. SCOPE:

The initial focus would be in Districts 1 and 2 since NR 216 takes effect in these districts first.

IV. WHAT SPECIFIC RESULTS, FINDINGS, TOOLS, ETC., DO YOU EXPECT?

We expect to find an approach to reduce pollution from state highways.

V. WHAT WILL THE BENEFITS BE? (Please Describe -- Value to WisDOT, Transportation Facilities Impact, Improvement in Quality, Increase in Safety, etc. How can benefits be measured?)

Water quality would improve and the Department would be in compliance with regulation NR-216. The benefits would be measured based on analysis of storm water and discharge data. This analysis would be used in the development of a comprehensive storm water management plan, installation and maintenance of storm water best management practices, ongoing monitoring and remedial action when needed.

E32 + M22

VI. LENGTH OF RESEARCH PROJECT (TIME): One year

VII. TOTAL COST TO COMPLETE PROJECT: \$75,000 (Approved by C.O.R. - FY'97)
+ \$55,000 (Requested of C.O.R. - FY'99)
\$130,000

VIII. WHAT IS NEEDED TO IMPLEMENT AND USE THE RESULTS? (Please Describe -- Education, Training, Equipment, Change in Procedure, Change in Process, Start-up Costs, etc.):

There will be a change in procedure involving use of types of equipment and its frequency.

IX. WHEN ARE THE RESULTS NEEDED? Desirable Year: 1997 Latest Year: 2000

X. PLEASE WRITE IN THE APPROPRIATE CATEGORIES THE RESEARCH APPLIES TO:

- Maintenance/Roadsides
- Environmental Impact

XI. SUBMITTED BY (Name, Title, Affiliation, Address, Phone, FAX Numbers):

David Vieth, Director, Office of Highway Maintenance, Bureau of Program Management, Division of Highways, Room 951, 4802 Sheboygan Avenue, Box 7916, Madison, WI 53707-7916. Phone: 267-8999, FAX: 267-7856.

Richard Moss, Research Director, same address. Phone: 267-7830, FAX: 267-7856.

Send to: Karen Porter
Wisconsin Department of Transportation
Departmental Research Coordination Section
4802 Sheboygan Avenue, Rm 633
P.O. Box 7916
Madison, WI 53707-7916

Phone (608) 266-3199
FAX (608) 264-6667

For Reviewer's use Only

ATTACHMENT A4
TO THE DOT/DNR COOPERATIVE AGREEMENT

MEMORANDUM OF UNDERSTANDING
BY AND BETWEEN THE
WISCONSIN DEPARTMENT OF NATURAL RESOURCES
AND THE
WISCONSIN DEPARTMENT OF TRANSPORTATION
RELATING TO THE AUTHORIZATION OF STORM WATER DISCHARGES
TO WATERS OF THE STATE OF WISCONSIN

storm water discharge permit to a municipality, whichever is later; however, a phase-in period may be implemented based on the priorities established in Part II D. Screening methodology may be developed based on experience gained during previous field screening activities, and need not conform to the protocol in s. NR 216.07(3), Wis. Adm. Code

(3) Whenever any illicit discharge is identified by DOT field screening activities, the DOT shall promptly notify the DNR, or where a intergovernmental agreement exists, the WPDES permitted municipality. Within one year of the date of signing this MOU, DOT will establish a notification procedure. The DNR or municipality shall promptly take the appropriate action as required in Part V A.

(4) The innocuous non-storm water discharges listed below are not considered illicit discharges unless identified by either the DOT or the DNR as a significant source of pollutants into waters of the State, and may enter the DOT storm sewer system covered by this MOU.

- water line flushing
- landscape irrigation
- diverted stream flows
- uncontaminated ground water infiltration
- uncontaminated pumped ground water
- discharges from potable water sources
- foundation drains
- air conditioning condensate
- irrigation water
- lawn watering
- individual residential car washing
- flows from riparian habitats and wetlands
- dechlorinated swimming pool water
- street wash water
- fire fighting.

B. OTHER POLLUTION PREVENTION MEASURES: The DOT shall continue to operate or implement as needed, storm water best management practices for the DOT storm sewer system covered by this MOU. The best management practices include:

(1) Highway runoff management including the activities described below associated with DOT highway maintenance, shall be operated as may be agreed upon in DOT/DNR supplemental agreements identified in Part IV E.

(a) Street sweeping after snow melt with a "heavy sweep" of materials that accumulated during the winter.

(b) A salt minimization program for highways, roads, and bridges with due consideration given for loss of life or property.

WisDOT Street Sweeping Evaluation Work plan

March 10, 1999

This study is designed to evaluate the effectiveness of a high efficiency street sweeper for use on highways owned and operated by the Wisconsin DOT. The research work will be organized and implemented according to the following tasks.

Task 1 - Study Design
Subtask 1.1 - Site Selection
The test will be performed on Highway 894 between National Avenue and Oklahoma Avenue. This section of Highway 894 is a 6 lane divided highway with 3 distinct drainage areas and has suitable site characteristics to give good test results. The site characteristics include mountable curb, accurate traffic count capability, accessibility to collect monitoring samples, wide shoulders under the overpass to avoid the sweeper entering live traffic lanes, and electrical service at the site. The site is located in the City of West Allis, Milwaukee County, Wisconsin. Milwaukee County, the United States Geological Survey and WisDOT District 2 will perform the field work for this study.

The street sweeping evaluation will use a paired basin approach, the test basin will be swept periodically with a high efficiency street sweeper, while the control basin will never be swept. Regression relationships will be determined between the test and control basins for both sweeping and non-sweeping periods. The site is shown on the attached diagram.

Subtask 1.2 - Sampling Parameters
The storm water samples that will be collected from the site will be analyzed according to the schedule included in Attachment 1. The toxicity of the particles collected through sweeping will also be analyzed once during the study.

Subtask 1.3 - Laboratory Services Contract
WisDOT will have a direct contract with the State Laboratory of Hygiene (SLOH) for the analysis of the storm water samples. The analytical results of the storm water samples will be forwarded electronically to Rob Waschbusch, USGS. Likewise, a copy of the analytical results will be sent in paper form to Tom Martinelli, DOT. In addition, the USGS Iowa sediment lab will perform the particle size distribution analysis. The particle size distribution work will be incorporated into WisDOT's contract with the USGS rather than having a direct contract with the Iowa sediment lab.

Subtask 1.4 - Consultant Contract
The Street Sweeping workgroup will seek expert advice from Roger Sutherland throughout the course of this project to ensure success. The activities that have been identified for Mr. Sutherland to provide assistance with are reviewing and commenting on this work plan, providing training on the SIMPTM model, assisting a person with model calibration, and providing assistance at the end of the project with data interpretation.

Subtask 1.5 - Sweeping Schedule
A sweeping schedule of once per week will be adhered to for the duration of the study. The sweeping schedule will include the same day and time of day in which the segment of road will be swept. A contingency plan will be developed by WisDOT District 2 and sweeping operator to accommodate for weather conditions that are not conducive to sweeping. The weather conditions when sweeping will not occur are: 1) it is raining and runoff conditions exist; 2) it is snowing and the pavement has been covered, and 3) there is snow and ice on the pavement and the temperature is higher than freezing and excessive melt conditions exist. The contingency plan will recommend to sweeping the day following the designated sweeping day if sweeping is missed on the designated day. If it is impossible to sweep on the following day, sweeping will be delayed until the next week

on the designated sweeping day. If conditions are not conducive to sweeping that week, additional efforts will be made to insure that at not time does the interval between sweeping events exceed 2 weeks. The operator will record the date and time of sweeping.

The sweeper operation will be determined by the agreement which is made on the sweeper rental. However, the speed of the sweeper while sweeping the test site shall not exceed 5 to 6 miles per hour.

Subtask 1.6 - Sweeper Rental Agreement
DOT intends to use the Schwarze Industries EV Sweeper (formerly known as Enviro Whirl Technology) for this street sweeping evaluation.

Task 2 - Field data collection - *February, 1999 through July, 2000*
We will collect data from the test and control sections of highway using a paired basin approach as described in Task 1. This effort will be done cooperatively between WisDOT District 2, Milwaukee County and the USGS.

Baseline periods, where no sweeping occurs in the test basin will be used to define pollutant load and concentration relationships for runoff events between the test and control basins. These relationships will then be compared to pollutant load and concentration relationships found between each basin during test periods. Sweeping periods will have the test basin swept at a rate of once per week and the control basin not swept.

The sweeping and non-sweeping schedule has been selected to provide an equal number of sweeping versus non-sweeping samples from frontal, convective and winter runoff events. The schedule assumes that:

- winter runoff events will occur in December, January and February;
- convective precipitation events, which are thunderstorms and more likely to be associated with intense, high energy rainfall, will occur in May, June, July and August;
- frontal runoff events which are associated with warm or cold weather fronts will happen in April, September, October and November;
- and March will likely have a combination of winter-like events mixed with some frontal events.

The first baseline period will go from February, 1999 through March, 1999, the Sweeping period will run from April, 1999 through July, 1999, then a 1 to 2 week equilibration period followed by baseline monitoring in August and September, 1999. Sweeping will initiate again from October, 1999 through March, 2000 followed by another equilibration period and baseline monitoring until the study concludes in June, 2000.

The field data collection will consist of the following subtasks:

Subtask 2.1 - Background Monitoring *- February, 1999 through June, 2000.*
Background monitoring of the test and control sections will need to be done in order to draw conclusive results on the effectiveness of street sweeping at the end of the study. An equal number of samples that are planned during the testing period will need to be background samples for the study to be statistically valid.

Subtask 2.2 - Traffic Counts *- October, 1998 through July, 2000.*
A permanent traffic counter is available within the study site. Traffic counts are currently collected within the test area. The Planning Section of WisDOT will make the traffic count numbers available for the purposes of this study. Daily and 15 minute traffic counts from the period of background monitoring through the end of the study will be provided.

Subtask 2.3 - Highway Vacuuming - *March, 1999 through July, 2000.*
Vacuuming of the roadway will need to be done to determine the accumulation rates of particulate matter on the highway and the efficiency of street sweeping. Vacuuming will initially need to occur on a regular basis of once per week. If possible, within each test period, vacuum samples will be collected before and after a rainfall event and before and after a sweeping event to collect baseline information. In addition, a one time vacuuming across all lanes of traffic will be done to determine the particle build up across the highway and verify our assumption that most particles will be on the shoulders of the road. This one time sweep across all lanes will be coordinated with Milwaukee County for traffic control.

Two people from DOT District 2 will be responsible for performing the highway vacuuming. One staff is needed to run the vacuum and collect the samples and the other staff is needed for traffic control. The staff person performing the vacuum collection will wear a dust mask when transferring samples from the vacuum and between containers to protect the staff person from breathing in the highway particle samples. These two people will perform the vacuuming as scheduled with initial start up training and guidance from staff at the USGS. The vacuum will be provided by the USGS and stored by the District 2 Environmental Team in Waukesha. The material collected from the vacuuming operations will be delivered to the USGS offices in Madison for drying and sieving of the material.

Subtask 2.4 - Sweep - *March, 1999 through March, 2000*
The goal of the street sweeping evaluation is to determine the effectiveness of a high efficiency street sweeper at improving runoff water quality. Background samples will be taken before the sweeping begins and in between periods of sweeping, to compare the test and control sections. Sweeping will follow the schedule in Subtask 1.3 and is scheduled to start in April, 1999 and continue through March, 2000.

Subtask 2.5 - Monitor Sweeping Effectiveness - *March, 1999 through July, 2000*
Throughout the period of sweeping, water samples will be taken during appropriate storm events at both the test and control sections to determine the effect of sweeping. The storm water samples collected from the two sampling locations will be collected by DOT District 2 the same day as the storm event, and as close to the end of the storm as is possible. The USGS will have a phone line connected to the sampling locations, and will notify District 2 if a sample needs to be retrieved. The USGS will coordinate with DOT District 2 when a sample needs to be pulled from the sampler. It is planned that DOT District 2 staff and the USGS staff will meet in Lake Mills to transfer the samples. This process will ensure that the samples arrive at the USGS lab in a timely manner for lab preparation. The USGS will prepare the samples for the State Lab of Hygiene (SLOH) and the USGS Iowa sediment lab for analysis and ensure their delivery to the appropriate locations.

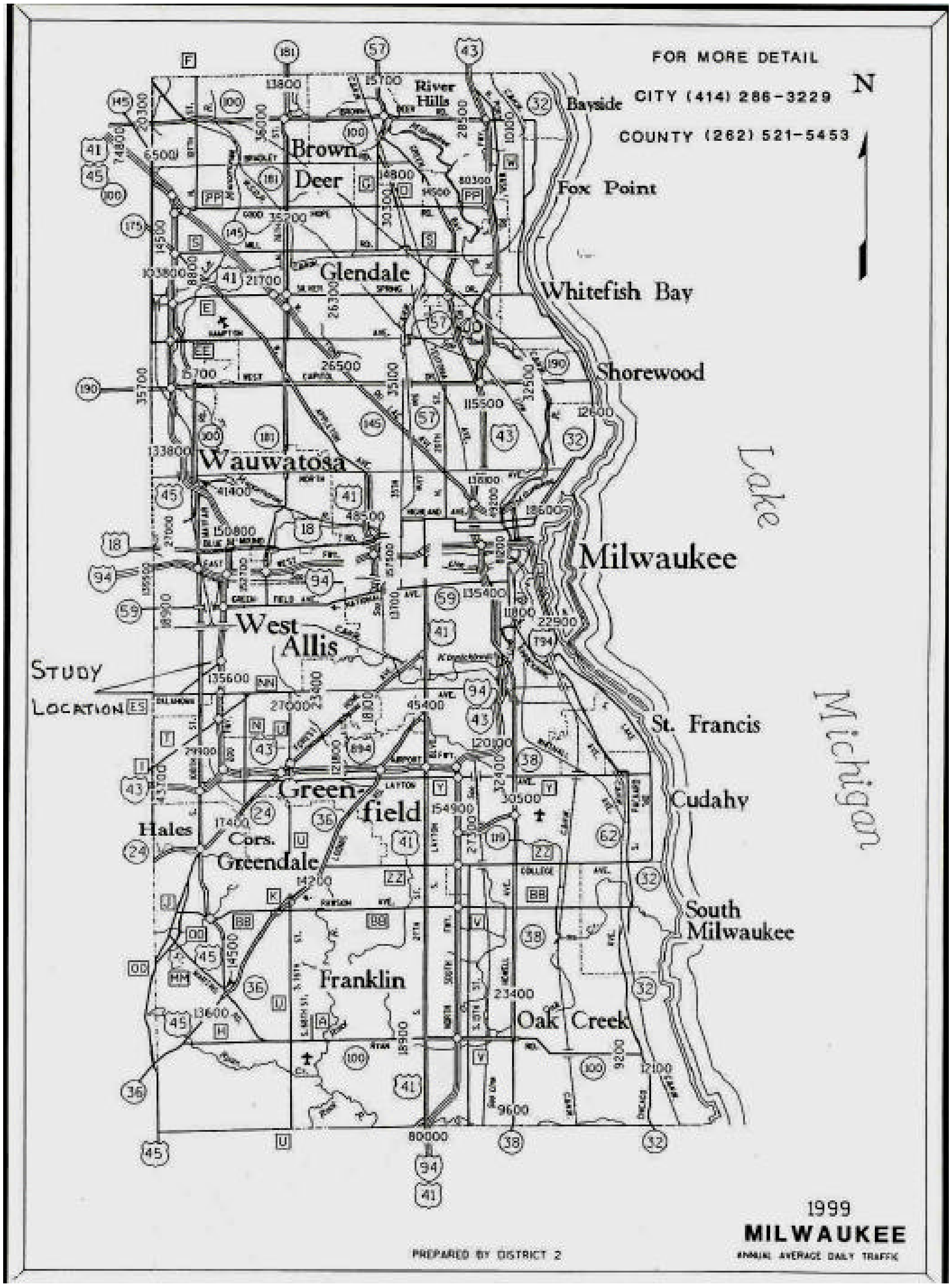
Task 3 - Model Calibration - *January, 1999 through October, 2000*
The results of the study will be used to calibrate the SIMP TM model. Roger Sutherland (Subtask 1.4) will provide guidance and training to the staff person identified to do this work. It is anticipated that this work will commence when there is enough monitoring data to work with and proceed on a continual basis as the monitoring data is collected. After the completion of data collection, work on model calibration will conclude by calibrating the SIMPTM model with the data that are collected from the research project.

Task 4 - Findings
Data analysis for this study will consist of interpretation and analysis of the data that is collected in Task 2 - Field Data Collection and the development of a final report. The findings of this study are described in detail by the subtasks that follow.

Subtask 4.1 - Data Analysis - *May, 1999 through September, 2000.*
Throughout the study, the water quality data that is collected will be analyzed by the USGS to identify the need for study design changes. Other team members may also review the data and will coordinate any recommendations for changes to the USGS. There will also be short briefing meetings throughout the course of study to keep a good flow of information on the data and needs for study design changes to team members.

Task 4.2 - Preparation of Data Report - *September, 2000 through November, 2000*
After the completion of the data collection, a data report will be prepared by the USGS that will describe the methods of collection and summarize the data collected for this study. The Data Report should be completed within a 60 day time period from the completion of Field Data Collection.

Task 4.3 - Preparation of Final Report - *October, 2000 through December, 2000*
The final report for this project will include the USGS data report, but will also include information from the model calibration and a conclusion on the effectiveness of the street sweeper for use on WisDOT highways. The report will also contain information learned about the operation and maintenance of the equipment and the practicality of using this equipment on a highway. If additional information on other sweeping frequencies is achieved through this study the report will also contain a discussion on optimal sweeping frequencies for street sweeping as a best management practice for WisDOT highways. The final report will be presented to the WisDOT Council on Research.



Study Location Map

ENVIROWHIRL PRODUCT LITERATURE

Enviro Whirl II Specifications

CLEANING AREA

Main Broom	71" (1.828m)
Secondary Broom	71" (1.828m)
Main Broom Diameter	18" (45.7cm)
Secondary Broom Diameter	12" (30.48cm)
Right Side Curb Broom	21" (53.32cm)
Total Sweeping Path	80" (2.514m)
Options:	
Auxiliary 6" suction hose port	
Auxiliary 6" suction hose 12' long	
Left side curb broom	
Total sweeping path with optional left curb broom	89" (2.26 m)

HOPPER

Volume	4.25 cu.yd (9.749 cm)
Capacity	6500 lbs. (2948 kg)
Conventional dump height	24"

DUST CONTROL SYSTEM

Type	dry cartridge polyester
Filter Type	2.9 micron media
Number of Filters	8
Media Area	640 sq.ft (59.45 m2)
Flash Point	300 degrees F (149 C)
Filter Cleaning System	Compressed air purged from within
Cleaning Sequence	sequential adjustable cleaning

HIGH SPEED FAN

Motor	hydraulic hi efficiency 46.9 hp
Fan Speed	3200 rpm
Airflow	11800 cfm (334m3/m)

Fan operates only in filtered air so no debris or dust comes in contact with blades allowing us to provide a lifetime warranty on fan

FOB FACTORY

Enviro Whirl Technologies, Inc.
2338 E. Calumet Street*Centralia, IL PHONE 618-532-3426 FAX 618-532-3844

DRIVE SYSTEM

Engine	John Deere 150 hp 6 cyl. turbo diesel Model 6068T
Engine Operating Speed	1800rpm
Hydrostatic Drive Motor	(2 ea.) Fluidrive 57cid/rev(934cm/u)
Engine Oil cooler	standard
Engine Pre-Heater	standard
Fuel Tank Capacity	54 gal. (U.S.) (204.39 lit.)

STEERING

4 wheel hydraulic steering

AXLES

Rear	EWT design trunion mount 18500 lbs (8391.6 kg)

Enviro Whirl Technologies

OPERATOR COMPARTMENT

Cab	Custom made 2 place steel/glass & sound insulated w/air conditioning & heater standard
Cab Location	Center mount directly above brooms for visibility

LIGHTING SYSTEM

Front	Quartz Halogen 180 degree
Rear	Stop/tail/back-up Safety Sequentially flashing directional advisor
Top Strobe	1,000,000 candlepower
Rear Strobe	1,000,000 candlepower

DIMENSIONS

Length	20'8" (6.29m)
Width	6'8" (2.03m)
Height	6'6" (1.98 m)
Empty Weight	19500 lbs (8840kg)
Gross Weight	30000 lbs (13599 kg)

REAR VISIBILITY PACKAGE

Package includes deluxe rear vision mirror system.
Option: Closed circuit TV rear mount

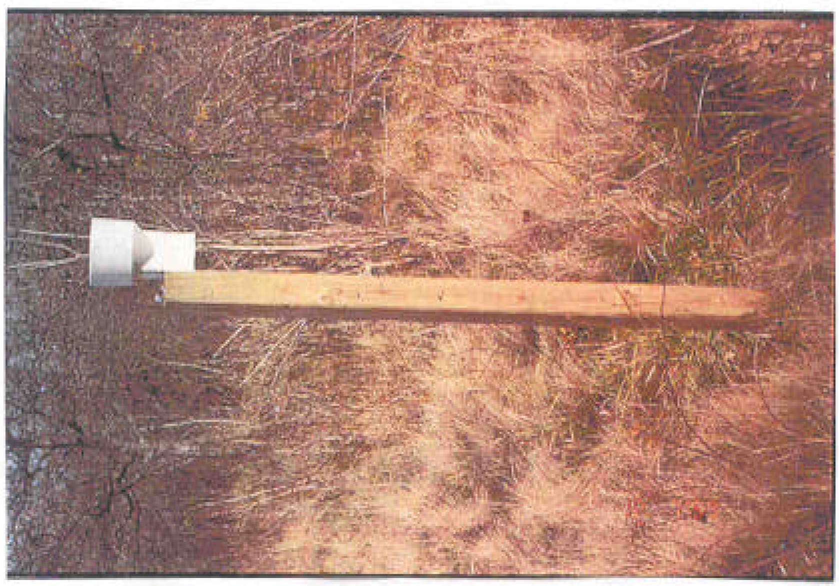
PARTS BOOK/REPAIR MANUAL/ TROUBLE SHOOTING GUIDE - 2 sets

AIR COMPRESSOR

Compressor	Curtis Toledo C-89 2 stage 68 cfm (1.93cm/m)
Compressor Motor	Eaton 2 Speed motor
Reserve Air Tank	20 gal (75.7 liters)

EnviroWhirl EV2 Photos

Field Sampling Equipment Photos



Field Sampling Equipment Photos

Median Area-Field Sampling Equipment Photos

Median Area-Field Sampling Equipment Photos

Culvert Flow Meter/ Vacuuming Equipment Photos

July 18, 1998

WDOT Street Sweeping Evaluation

Problem: The Wisconsin Department of Transportation (WDOT) is required to control the quality of runoff from roadways under their control as part of the National Pollution Discharge Elimination System (NPDES). One way to control roadway runoff is to use street sweeping to remove pollutants before they are entrained in runoff. This option would be preferable to structural BMPs since WDOT already conducts street sweeping and would only need to increase the sweeping frequency and obtain an improved sweeper.

Objectives:

The primary objective of this project is to determine if water quality benefits are realized by street sweeping and if so to what degree.

Secondary objectives are:

1. Develop dirt accumulation curves for freeways in Milwaukee.
2. Use the dirt accumulation and water quality data to calibrate the SMTM model.
3. Characterize the variability in freeway runoff quality.

Additionally the data may be used to determine if a relation exists between traffic count and runoff concentration.

Methods: This study will use a paired basin approach, the test basin will be swept periodically with an Enviro-Whirl street sweeper and the control basin will never be swept. Regression relationships will be determined between the test and control basins for both sweeping and non-sweeping periods. If the slope and intercept of the regression relationships are significantly different between the sweeping and non-sweeping periods, the difference will be attributed to the street sweeping.

WDOT will contract to rent or lease an Enviro-Whirl vacuum sweeper, which will be used to clean the test basin during sweeping periods. The study basins will be adjacent sections of an urban freeway in Milwaukee and have gutters and inlets draining to a pipe that can be monitored for flow and water quality. Each basin will be equipped with a data logger, area-velocity meter, modem and phone, ISCO sampler, and rain gage. AC power will be necessary for battery chargers, refrigerators, area-velocity meter and heating tapes on sampler intakes. USGS will supply all the monitoring equipment mentioned. WDOT will pay the costs of getting the power to the monitoring stations and the monthly electricity and phone bills.

Baseline periods, where no sweeping occurs in either the test or control basin, will be used to define pollutant load and concentration relationships for runoff events between the basins. These relationships will then be compared to pollutant load and concentration relationships found between the basins during test periods. Sweeping periods will have the test basin swept at a rate of once per week and the control basin unswept. The sweeping and non-sweeping schedule has been selected to provide an equal number of sweeping versus non-sweeping samples from frontal, convective and winter runoff events. The planned schedule is:

Field Sampling Plan

	Number of Samples	
Period	Sweeping	No Sweeping
Nov '98		4
Dec '98		1
Jan '99		2
Feb '99		2
Mar '99		4
Apr '99	4	
May '99	4	
Jun '99	4	
Jul '99	4	
1-2 week equilibration period		
Aug '99		4
Sep '99		4
Oct '99	4	
Nov '99	4	
Dec '99	1	
Jan '00	2	
Feb '00	2	
Mar '00	4	
1-2 week equilibration period		
Apr '00		4
May '00		4
Jun '00		4
Total	33	33

The schedule assumes that samples collected in:

Dec., Jan., and Feb. will be winter runoff events
May, Jun., Jul., and Aug., will be convective precipitation events (thunderstorms),
Apr., Sep., Oct., and Nov., will be frontal runoff events
Mar., will probably be some winter-like runoff events and some frontal events.

If sample collection proceeds according to schedule, samples will be collected from:

28 frontal events, 14 swept and 14 unswept,
24 convective events, 12 swept and 12 unswept
14 winter events, 7 swept and 7 unswept.

The schedule also has 2 equilibration periods in it, which are meant to allow the street dirt levels to rise back up to baseline levels after a sweeping period concludes.

Initially all sweeping period data will be grouped together for comparison to all non-sweeping period data. If it is found that the relationships for the different types of runoff events are different, the data will be sorted on that basis and separate comparisons will be made. Unfortunately sorting reduces the number of data points and makes differences more difficult to detect.

One potential problem with this sampling design is that inefficient bedload sampling, (heavy material that is not efficiently collected by autosamplers), may prevent the complete effectiveness of the street sweepers from being shown. Unfortunately, major effort, far beyond the scope and budget of this study, would be required to determine the affects of bedload. Some estimates of bedload based on previous studies may be applied (Waschbusch 1998).

WDOT or a company contracted by them will be responsible for getting the highway shoulders swept on schedule. Both the inner and outer shoulders will be swept. A diagram of the highway sweeping pattern is shown below.

The study will result in 66 storm samples from each site for a total of 132 runoff water quality samples. An additional 28 samples (~17%) will be collected for quality assurance bringing the total number of samples to 160. Concentrations of the following constituents will be determined at the Wisconsin State Laboratory of Hygiene:

	RVU	Analysis	total	Number of samples	total cost
COD	$8.65	2	$17.30	20	$346
Ammonia-Nitrogen	$8.65	2	$17.30	160	$2,768
NO2 + NO3	$8.65	2	$17.30	160	$2,768
Total Phosphorus	$8.65	1.5	$12.98	160	$2,076
Diss. Phosphorus	$8.65	1.9	$16.44	160	$2,630
Suspended Solids	$8.65	1.9	$16.44	160	$2,630
Total Dissolved Solids	$8.65	1.9	$16.44	20	$329
Chloride, Automated	$8.65	1.5	$12.98	160	$2,076
Copper, Tot. Recov Low Level, AA Furn	$8.65	2.9	$25.09	160	$4,014
Copper, Diss AA Furn	$8.65	2.6	$22.49	20	$450
Zinc, Tot. Recov., ICP	$8.65	1.2	$10.38	160	$1,661
Zinc, Diss., ICP	$8.65	0.4	$3.46	20	$69
Digestion Tot. Low Level, AA Furn	$8.65	2	$17.30	160	$2,768
Digestion, Tot. Recov., Liquids ICP	$8.65	2	$17.30	160	$2,768
ICP set-up & test	$8.65	0.8	$6.92	160	$1,107
Estimated Total Cost					$28,459

The WDOT will contract separately with the SLOH for analysis. In addition 160 samples will be sent to the USGS sediment laboratory in Iowa for sand-silt split particle size analysis. The cost of these analyses will be $5002.

USGS will train WDOT to pick-up water samples from the monitoring stations. WDOT will then transport the water samples to a Lake Mills drop-off location. USGS will then transport the water samples to the USGS lab in Madison for processing and afterwards will deliver the samples to the Wisconsin State Laboratory of Hygiene and the USGS Iowa sediment lab for analysis.

In addition to water samples, vacuum samples will be collected to determine the rate of dirt build up on the highway. These samples will be collected using equipment similar to that described in Pitt (1979). WDOT will collect vacuum samples 1x/week from the right shoulder of both the test and control basins for the duration of the study. A few vacuum samples will also be collected before and after a sweeper pass. Vacuum samples will be used to develop dirt accumulation and wash-off rates and sweeping efficiency for input into the SMTM model. USGS will train WDOT in the sampling methods and supply the vacuum. (Can DOT supply generator? trailer?)

Initially approximately 30 subsamples will be collected and dried and weighed individually, in both the test and control sections to determine the variability in dirt loads along the highway. This variability will be used to calculate the number of subsamples that need to be composited to accurately represent the highway dirt load using the following equation (Hansen et al 1984):

$$N = \frac{4.25\,(s-1)^2}{(ra)^2}$$

where, a = mean
s = standard deviation
r = allowable error
N = number of subsamples required

These initial samples will be collected by the USGS and WDOT and will serve as the training period. USGS will perform the statistical analysis on the data to determine the number of samples required for the 1x/week vacuum sampling.

There will also be a one-time effort to determine the distribution of dirt across the highway. For this effort vacuum samples will be collected from 5 locations across the highway:

1. The swept portion of the right shoulder (the width of the sweeper)
2. The unswept portion of the right shoulder (the remainder of the shoulder)
3. The traffic lanes
4. The unswept portion of the left shoulder
5. The swept portion of the left shoulder

USGS will dry, sieve and weigh vacuum samples to determine the particle size distributions. The dirt samples will be sieved into the following 4 size fractions:

1. > 250 µm
2. 125-250 µm
3. 62-125 µm
4. < 62 µm

WDOT will need to maintain accurate records of when streets were swept. WDOT will also collect 15 minute traffic counts for the entire length of the study and provide them to USGS.

Data analyses will be performed jointly by USGS and WDOT and will summarize the efficiency of the sweeping operation. Accumulation rates of constituent buildup on the street surface and the runoff loads will be developed for input into the SMTM model. All data will be stored in the USGS data base and available.

References:

Hansen, J., Sesing, M., Hughes, P., and Graczyk, D. 1984., Evaluation of Urban Nonpoint Source Pollution Management in Milwaukee County, Wisconsin. Vol. III., Study Site Characteristics, Experimental Methods and Quality Assurance Program. Wisconsin Department of Natural Resources, PB 84-114180.

Pitt, R. 1979, Demonstration of Nonpoint Pollution Abatement Through Improved Street Cleaning Practices. USEPA, Cincinnati, Ohio, Report No. EPA-600/2-79-161.

Waschbusch, R.J., 1998. Evaluation of an Urban Best M (in press).

5/28/99

Dear Tom, Roger, Anna and Alice,

As a result of several delays, (electric service, sampling equipment problems and Enviro-Whirl sweeper agreement), the original sample collection schedule is out of whack. The original schedule would have resulted in sampling 7 winter, 14 frontal and 12 convective events that were both swept and unswept (a total of 66 events) and sampling would conclude in by the end of June 2000. Given our current status, if we stick to the original sampling schedule from this point forward, we will end up with 1 winter, 11 frontal and 12 convective unswept runoff events and 7 winter, 10 frontal and 10 convective swept runoff events (a total of 51 events). From a statistical perspective, we'd like to have equal numbers of the swept and unswept samples from each type of event (winter, frontal and convective). We would also like to collect as many samples as we have budgeted for. I have adjusted the schedule around to try to minimize these problems, but I'm receptive to other ideas to accomplish these goals. To accomplish the changes that I am suggesting a few things will need to change and I am interested in your opinion as to if these changes are acceptable.

If we proceed with the original schedule:

Period	Number of samples: Sweeping	Number of samples: Non-Sweeping
Mar '99		1
Apr '99		3
May '99	2	
Jun '99	4	
Jul '99	4	
1-2 week equilibration period		
Aug '99		4
Sep '99		4
Oct '99	4	
Nov '99	4	
Dec '99	1	
Jan '00	2	
Feb '00	2	
Mar '00	4	
1-2 week equilibration period		
Apr '00		4
May '00		4
Jun '00		4
Jul '00		0
Total	27	24

My proposed schedule adjustments:

Period	Number of samples: Sweeping	Number of samples: Non-Sweeping	
Mar '99		1	
Apr '99		3	
May '99	2		
Jun '99	5		
Jul '99	5		
Aug '99	4		(make sweep period)
1-2 week equilibration period			
Sep '99		4	
Oct '99	6		
Nov '99	5		
Dec '99	2		
Jan '00	2		
1-2 week equilibration period			
Feb '00		2	(make this a non-sweep period)
Mar '00	2	2	(non-sweep to start then switch
1-2 week equilibration period			
Apr '00		5	to sweeping)
May '00		5	
Jun '00		5	
Jul '00		5	
Aug '00		1	(extend sampling end date)
Total	33	33	

	Non sweeping					Non sweeping	
winter	frontal	convective	total	winter	frontal	convective	total
1	11	12	24	4	13	16	33

	Sweeping				Sweeping		
winter	frontal	convective	total	winter	frontal	convective	total
7	10	10	27	4	13	16	33

Notice that the original schedule had a non-sweeping period during August and September 1999 and the revised schedule has reduced this period to September only. During this period was the sweeper scheduled to go back to Osceola? If so would they agree to this? Additionally, the sample collection period has been extended into August 2000. If this occurs, the lab results will most likely not be available until about October 2000 and the report won't be finished until around spring of 2001. The USGS will not require additional funding to extend the timeline but we would need to resign the agreement with modified completion dates to allow for carrying some of the funds into fiscal year 2001 (October 2000 to September 2001). Is this acceptable to DOT?

On a final note, even with this schedule revision some luck will be necessary to meet the sampling goals. I had to make some optimistic estimates to meet the original target sample numbers and still keep the timetable reasonably close to the original plan.

Sincerely,

Rob Waschbusch

cc: Tom Martinelli
Anna Sundberg
Alice Klink
Roger Bannerman

STREET SWEEPING DIARY

DATE

TIME

WEATHER

Cloud Cover	**Sunny**	**Partly Cloudy**	**Overcast**
Wind	**Windy**	**Calm**	
Temperature			
PAVEMENT CONDITIONS	**Dry**	**Damp**	**Wet**

HOUR METER **Begin Time**

End Time

Operational Observations (malfunctions, repairs, adjustments)

OPERATOR NAME

WEIGHT OF MATERIAL

THE IMPACT OF A FREEWAY SWEEPING PROGRAM
STUDY TIME LINE

DATE	EVENT
1/15/96	Study proposal submitted to Council on Research (C.O.R.) for consideration.
7/9/96	Study funding of $38,600 for FY ’97 and $36,400 for FY ’98 approved by C.O.R.
10/3/96	Study Technical Oversight Committee membership solicited
10/8/96	Solicitation for study principal investigator
12/11/96	Meeting #1 of Technical Oversight Committee (T.O.C.)
1/9/97	Meeting #2 of Technical Oversight Committee (T.O.C.)
2/13/97	Meeting #3 of Technical Oversight Committee (T.O.C.)
4/18/97	Meeting #4 of Technical Oversight Committee (T.O.C.)
11/17/97	Meeting #5 of Technical Oversight Committee (T.O.C.)
1/21/98	Meeting #6 of Technical Oversight Committee (T.O.C.)
4/2/98	Additional study funding ($55,000) requested of C.O.R. for FY ‘99
5/5/98	Meeting #7 of Technical Oversight Committee.
6/8/98	Meeting #8 of Technical Oversight Committee. (Held at Milwaukee County Public Works Department)
8/24/98	Study status meeting of WisDOT and WDNR T.O.C. members
2/11/99	Meeting #9 of Technical Oversight Committee
3/1/99	Background field sampling begins
3/25/99	SIMPTM Model Training session
5/11/99	Freeway sweeping schedule begins
12/7/99	Meeting #10 of Technical Oversight Committee (Held at Milwaukee County Public Works Department)
3/15/00	Freeway Sweeping schedule ends
9/19/00	Background field sampling ends

Table A1. Test Site Event Runoff Summary

Test Site

Event Number	Date	total precipitation (in.)	Runoff Volume during storm (ft^3)	Peak Runoff during storm (cfs)	Runoff Volume during sampling (ft^3)	Peak Runoff during sampling (cfs)	percent runoff	percent sampled
1	3/11/99	snowmelt	743	0.021	743	0.021	-	100%
2	4/11/99	0.26	734	0.253	734	0.253	17%	100%
3	4/16/99	0.26	1,270	0.059	1,253	0.059	30%	99%
4	4/21/99	0.95	3,871	1.092	3,836	1.092	25%	99%
5	5/21/99	0.17	2,004	1.092	1,452	1.092	71%	72%
6	5/23/99	0.5	4,830	5.944	3,715	5.944	58%	77%
7	6/10/99	1.17	11,448	8.782	11,189	8.782	59%	98%
8	6/16/99	0.16	1,901	0.846	1,685	0.846	72%	89%
9	6/23/99	0.15	1,279	0.846	985	0.846	52%	77%
10	6/28/99	0.83	5,201	5.432	4,847	5.432	38%	93%
11	7/6/99	0.09	518	0.846	458	0.846	35%	88%
12	7/9/99	2.45	28,140	15.526	26,196	15.526	69%	93%
13	7/16/99	1.26	17,038	2.286	16,623	2.286	82%	98%
14	7/21/99	1.85	16,537	12.282	16,088	12.282	54%	97%
15	7/31/99	0.31	3,050	2.909	2,523	2.909	59%	83%
16	8/7/99	0.32	2,946	1.395	2,756	1.395	56%	94%
17	8/10/99	0.22	2,056	3.972	1,961	3.972	56%	95%
18	8/18/99	0.55	7,309	1.092	6,869	1.092	80%	94%
19	8/23/99	0.24	2,411	2.286	2,281	2.286	61%	95%
20	9/19/99	0.5	4,821	8.537	4,562	8.537	58%	95%
21	9/27/99	0.13	1,356	0.618	1,192	0.618	63%	88%
22	9/27/99	2.36	20,624	2.198	19,051	2.198	53%	92%
23	10/3/99	0.57	7,448	1.092	7,214	1.092	79%	97%
24	10/16/99	0.29	4,242	0.846	4,035	0.846	88%	95%
25	11/10/99	0.49	5,003	3.229	4,864	3.229	62%	97%
26	11/23/99	0.21	3,361	1.595	3,007	1.595	97%	89%
27	11/23/99	0.12	924	0.846	665	0.846	47%	72%
28	12/14/99	snowmelt	1,452	0.149	1,287	0.149	-	89%
29	1/3/00	snowmelt	6,299	0.105	5,495	0.105	-	87%
30	2/18/00	snowmelt	9,469	0.086	9,314	0.086	-	98%
31	2/21/00	snowmelt	3,335	0.105	3,257	0.105	-	98%
32	2/24/00	snowmelt	5,581	0.846	5,357	0.846	-	96%
33	4/7/00	snowmelt	10,040	1.595	10,040	1.595	-	100%
34	5/9/00	1.13	9,167	1.699	5,538	1.699	49%	60%
35	5/17/00	1.7	7,914	3.744	7,370	3.744	28%	93%
36	6/1/00	0.38	5,383	5.944	5,244	5.944	86%	97%
37	6/4/00	0.46	8,389	2.103	8,407	2.103	110%	100%
38	6/14/00	0.36	2,843	7.577	2,808	7.577	48%	99%
39	6/20/00	0.21	2,497	3.858	2,281	3.858	72%	91%
40	7/28/00	1.74	13,997	4.427	13,789	4.427	49%	99%
41	8/5/00	2.61	29,212	4.785	10,765	4.785	68%	37%
42	8/17/00	2.17	26,473	3.435	3,612	2.802	74%	14%
43	8/17/00	0.06	622	0.069	622	0.069	63%	100%

44	8/26/00	0.84	5,556	12.157	5,521	12.157	40%	99%
45	9/7/00	0.21	2,886	2.286	2,376	2.286	83%	82%
46	9/10/00	0.48	5,910	4.006	5,841	4.006	74%	99%
47	9/14/00	0.86	15,180	1.894	9,435	1.806	107%	62%
48	9/19/00	0.42	6,134	0.846	5,918	0.846	88%	96%
OKM-11	9/22/00	0.89						
						mean	62%	
						standard deviation	21%	

Table A2. Control Site Event Runoff Summary

Control Site

Event ```````````	Date	total precipitation (in.)	Runoff Volume during storm (ft^3)	Peak Runoff during storm (cfs)	Runoff Volume during sampling (ft^3)	Peak Runoff during sampling (cfs)	percent runoff	percent sampled
1	3/11/99	snowmelt	1,638	0.0334	1,552	0.0334	-	95%
2	4/11/99	0.26	1,486	0.827	1,339	0.827	29%	90%
3	4/16/99	0.22	804	0.1002	648	0.1002	18%	81%
4	4/21/99	0.89	5,625	1.436	5,417	1.436	32%	96%
5	5/21/99	0.15	467	0.1986	337	0.1986	16%	72%
6	5/23/99	0.20	2,316	3.17	2,316	3.17	58%	100%
7	6/10/99	1.07	5,219	3.56	4,899	3.56	24%	94%
8	6/16/99	0.13	467	0.2502	302	0.2502	18%	65%
9	6/23/99	0.14	510	0.573	423	0.573	18%	83%
10	6/28/99	0.75	4,380	4.134	4,173	4.134	29%	95%
11	7/6/99	0.10	372	1.0148	130	0.7254	19%	35%
12	7/9/99	2.14	13,116	5.61	11,241	5.61	31%	86%
13	7/16/99	1.09	6,618	1.862	6,342	1.862	30%	96%
14	7/21/99	1.51	9,245	6.35	8,044	6.35	31%	87%
15	7/31/99	0.28	1,555	1.862	1,339	1.862	28%	86%
16	8/7/99	0.32	1,901	1.686	1,719	1.686	30%	90%
17	8/10/99	0.22	1,236	2.576	1,115	2.576	28%	90%
18	8/18/99	0.58	4,044	1.95	3,923	1.95	35%	97%
19	8/23/99	0.20	890	0.573	544	0.1986	22%	61%
20	9/19/99	0.58	3,750	5.25	3,542	5.25	32%	94%
21	9/27/99	0.13	804	0.2502	622	0.2502	31%	77%
22	9/27/99	2.16	17,366	2.46	15,587	2.46	40%	90%
23	10/3/99	0.54	2,091	0.3408	1,909	0.3408	19%	91%
24	10/16/99	0.30	1,331	0.7762	1,227	0.7762	22%	92%
25	11/10/99	0.50	3,110	3.69	2,791	3.69	31%	90%
26	11/23/99	0.22	769	0.57	752	0.57	17%	98%
27	11/23/99	0.12	458	0.6746	320	0.6746	19%	70%
28	12/14/99	snowmelt	717	0.0746	458	0.0746	-	64%
29	1/3/00	snowmelt	2,100	0.0874	1,970	0.0874	-	94%
30	2/18/00	snowmelt	959	0.0282	708	0.023	-	74%
31	2/21/00	snowmelt	916	0.0386	829	0.0386	-	91%
32	2/24/00	snowmelt	1,814	0.4114	1,650	0.4114	-	91%
33	4/7/00	snowmelt	2,125	0.1344	2,074	0.1344	-	98%
34	5/9/00	0.80	4,380	0.6746	2,765	0.6746	27%	63%
35	5/17/00	1.70	5,504	3.17	5,426	3.17	16%	99%
36	6/1/00	0.38	5,115	2.358	4,571	2.358	67%	89%
37	6/4/00	0.46	3,300	0.5326	3,205	0.5326	36%	97%
38	6/14/00	0.33	1,521	2.576	916	2.358	23%	60%
39	6/20/00	0.24	1,313	2.576	1,011	2.576	27%	77%
40	7/28/00	1.74	9,046	2.808	8,104	2.808	26%	90%
41	8/5/00	2.61	18,559	3.56	2,350	3.56	36%	13%
42	8/17/2000	2.17	14,403	2.154	2,039	1.95	33%	14%
43	8/17/2000	0.07	389	0.07	389	0.07	28%	100%
44	8/26/2000	0.84	3,067	4.134	2,730	4.134	18%	89%

45	9/7/2000	0.27	1,175	1.686	942	1.598	22%	80%
46	9/10/2000	0.48	2,704	2.692	2,385	2.692	28%	88%
47	9/14/2000	0.84	5,115	2.256	2,609	0.5326	30%	51%
48	9/19/2000	0.47	1,754	0.1344	1,477	0.1344	19%	84%
						mean	28%	
						standard deviation	10%	

Table A3. Street dirt collected by vacuum sampling at the test site

Collection Date	street dirt (grams/collection swipe)	Percentage Street Dirt in Size Fractions by Mass >6.37mm	6.37-2.0 mm	2.0-1.0 mm	1.0-0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.0625 mm	<0.0625 mm
4/1/1999	50.52	5.34	12.17	10.98	16.33	26.14	20.04	4.92	4.08
4/13/1999	27.71	7.5	14.75	9.37	14.85	23.49	18.14	5.98	5.92
4/21/1999	14.67	12.74	22.64	11.68	12.96	18.09	15.35	3.96	2.57
4/29/1999	18.33	3.58	29.67	13.55	17.3	20.42	11.09	3.28	1.12
6/14/1999	22.00	7.8	13.2	11.95	17.64	24.61	18.27	4.97	1.56
6/16/1999	9.42	11.86	21.25	10.27	13.65	21.76	14.96	4.48	1.77
6/30/1999	8.42	14.31	16.28	10.11	14.22	21.58	16.57	5.34	1.59
7/26/1999	7.21	26.9	23.06	11	12.65	14.44	8.79	2.49	0.67
7/28/1999	6.38	39.27	16.91	7.68	8.79	12.3	9.51	3.93	1.6
8/9/1999	4.96	13.75	19.81	13.49	16.61	19.8	10.29	3.89	2.36
8/11/1999	3.88	24.52	20.34	10.43	11.14	14.6	11.26	5.2	2.51
8/25/1999	10.71	12.96	14.92	9.51	18.74	24.11	12.5	4.14	3.12
9/1/1999	9.71	17.37	15.22	9.5	15.09	21.91	14	4.79	2.11
9/10/1999	16.75	14.28	19.23	13.05	16.4	20.14	12.05	3.34	1.5
9/13/1999	9.71	28.4	14.94	11.39	14.52	16.29	9.85	3.08	1.53
9/20/1999	3.92	20.12	16.49	12.14	14.05	18.53	14.53	3.58	0.56
9/29/1999	17.88	15.09	14.25	12.09	17.96	23.09	12.79	3.23	1.5
########	11.63	19.4	17.65	13.29	17.38	17.79	9.46	3.15	1.88
########	17.67	15.84	18.92	13.93	16.88	18.43	10.33	3.34	2.33
11/1/1999	21.79	20.64	17.81	10.8	15.07	18.94	9.61	3.49	3.64
11/3/1999	11.00	23.88	16.30	9.13	13.98	18.85	11.18	4.03	2.66
########	12.92	11.38	15.88	14.87	19.00	22.29	10.97	3.37	2.25
########	7.38	15.02	18.10	12.99	16.50	20.53	11.23	3.86	1.77
########	6.54	12.78	19.30	16.76	19.62	18.66	9.08	2.68	1.12
12/1/1999	4.29	12.87	16.29	10.30	13.11	18.69	13.31	6.20	9.22
########	13.88	13.16	26.42	21.01	16.11	14.48	6.08	1.68	1.05
1/10/2000	22.21	12.78	21.80	18.71	23.98	19.03	2.93	0.31	0.46
1/12/2000	27.71	5.50	8.67	11.75	19.07	29.45	15.16	6.48	3.92
1/24/00 *	8.21	-	-	-	-	-	-	-	-
1/31/00 *	62.21	-	-	-	-	-	-	-	-

2/1/2000	7.58	13.39	20.55	11.35	10.70	18.69	13.97	6.77	4.59
2/28/2000	162.58	1.96	7.69	9.06	27.83	32.38	14.21	4.89	1.99
2/29/2000	23.63	7.46	12.54	10.52	17.35	23.54	16.37	8.81	3.42
3/13/2000	14.42	9.80	16.31	12.52	18.19	22.89	11.80	5.29	3.20
3/27/2000	25.58	10.20	11.78	10.26	19.35	27.78	13.58	4.30	2.75
4/3/2000	27.08	9.04	14.09	9.72	15.55	25.44	14.88	6.42	4.87
4/14/2000	43.96	11.33	21.22	14.87	16.32	18.25	11.15	4.01	2.84
4/18/2000	62.54	8.58	14.12	13.79	20.24	23.86	12.49	4.48	2.43
4/24/2000	37.13	7.73	10.50	12.38	21.42	28.41	13.91	3.52	2.13
5/5/2000	111.92	6.20	10.44	10.69	18.88	28.78	17.85	4.34	2.83
5/15/2000	7.58	17.03	13.31	7.38	15.06	25.46	15.34	4.50	1.92
6/7/2000	293.38	5.71	10.42	10.61	22.46	31.06	14.98	3.09	1.67
6/14/2000	8.17	16.21	13.49	10.49	16.21	22.00	14.20	5.30	2.09
6/21/2000	8.96	35.94	11.79	11.42	11.64	14.87	9.98	3.08	1.29
6/30/2000	22.38	15.39	14.62	13.51	17.68	21.27	12.10	3.39	2.03
7/7/2000	8.42	20.52	18.14	10.47	17.63	20.31	9.55	2.47	0.91
7/10/2000	4.33	31.55	15.44	9.49	12.89	16.00	10.56	3.06	1.01
7/21/2000	13.67	25.94	21.31	10.68	13.57	16.43	8.78	2.43	0.86
7/26/2000	17.17	16.97	20.20	14.07	16.53	16.68	10.43	3.48	1.65
8/4/2000	54.63	11.64	10.79	10.20	19.48	27.94	14.15	3.51	2.28
8/7/2000	17.25	19.24	14.21	9.37	14.64	22.59	12.69	5.11	2.16
8/14/2000	12.92	26.30	18.47	10.28	15.58	16.88	9.10	2.51	0.87
8/21/2000	31.33	27.74	18.36	11.37	13.17	16.51	9.29	2.70	0.87
8/29/2000	4.00	9.52	16.53	13.18	17.67	20.38	14.68	5.65	2.39
9/5/2000	6.42	26.22	18.27	10.49	13.46	17.25	10.26	3.15	0.90
9/12/2000	5.08	9.47	9.85	8.84	22.78	32.79	12.81	2.92	0.54
9/18/2000	8.29	25.06	19.11	8.35	12.38	16.83	12.39	4.56	1.32
9/25/2000	4.92	23.01	15.22	9.00	14.57	19.65	13.03	4.50	1.03

* not sieved due to caking while drying

sweeping period data

Table A4. Street dirt collected by vacuum sampling at the control site

Collection Date	street dirt (grams/collection swipe)	Percentage Street Dirt in Size Fractions by Mass >6.37mm	6.37-2.0 mm	2.0-1.0 mm	1.0-0.5 mm	0.5-0.25 mm	0.25-0.125 mm	0.125-0.0625 mm	<0.0625 mm
4/1/1999	31.21	11.4	23.18	14.66	15.26	16.95	11.38	3.75	3.42
4/13/1999	23.36	9.26	34.69	17.28	12.95	11.37	7.33	3.91	3.2
4/21/1999	113.29	4.83	24.47	20.78	21.77	16.96	7.57	2.04	1.58
4/29/1999	17.14	13.24	33.74	15.1	12.42	11.59	7.66	3.88	2.36
6/14/1999	2.90	25.8	21.67	9.91	9.47	12.38	11.91	6.31	2.54
6/16/1999	7.36	24.39	31.65	10.56	7.81	8.94	7.31	5.1	4.25
6/30/1999	10.29	15.61	39.19	15.13	9.5	9.9	6.48	3	1.19
7/26/1999	10.14	14.36	25.67	12.25	16.07	19.1	8.53	2.98	1.05
7/28/1999	12.29	42.22	21.42	8.04	8.54	10.29	5.38	2.64	1.46
8/9/1999	4.36	14.86	34.85	14.55	10.37	10.26	6.28	4.52	4.31
8/11/1999	19.79	24.01	28.56	14.49	13.67	12.86	4.12	1.43	0.85
8/25/1999	10.00	28.55	27.76	12.76	10.58	10.6	5.64	2.5	1.61
9/1/1999	10.29	23.35	31.04	11.76	10.68	12.08	6.45	2.77	1.87
9/10/1999	29.50	16.76	27.59	14.96	14.19	14.54	6.28	2.88	2.8
9/13/1999	7.29	32.83	20.43	13.67	10.14	11.11	6.72	3.29	1.83
9/20/1999	3.64	24.66	16.99	13.31	11.64	12.72	11.17	6.1	3.41
9/29/1999	5.29	32.41	16.92	8.8	7.43	13.16	13.08	6.17	2.04
########	23.36	22.7	30.8	18.56	11.51	9.03	4.8	1.72	0.89
########	44.50	15.74	32.21	14.83	12.93	14.18	6.43	2.43	1.24
11/1/1999	47.07	16.44	29.15	16.55	14.94	12.62	6.37	2.2	1.74
11/3/1999	42.71	19.65	27.69	16.02	13.87	12.96	6.12	2.35	1.33
########	46.00	10.27	24.69	15.36	15.34	18.04	9.06	4.15	3.09
########	13.93	23.39	22.88	15.52	14.45	12.35	6.76	3.04	1.62
########	5.21	18.61	35.60	13.93	10.66	9.91	5.93	3.45	1.92
12/1/1999	51.21	11.87	23.79	17.43	17.60	16.87	7.48	3.19	1.75
########	44.86	12.08	27.96	19.49	16.77	13.49	6.28	2.38	1.55
1/5/2000	17.57	20.56	22.20	17.14	16.25	14.20	5.16	2.16	2.32
1/10/2000	35.50	12.39	28.74	17.81	19.81	16.48	3.66	0.53	0.56
1/12/2000	49.79	8.05	20.72	14.51	17.13	22.37	10.75	4.07	2.39

1/24/00 *	13.93	-	-	-	-	-	-	-	-
1/31/00 *	69.57	-	-	-	-	-	-	-	-
2/1/2000	7.71	5.51	24.30	14.14	14.95	23.77	12.39	3.04	1.91
2/28/2000	72.86	8.34	14.89	14.47	17.80	18.65	11.25	7.94	6.67
2/29/2000	49.71	10.76	20.28	14.79	16.49	16.87	9.43	5.96	5.42
3/13/2000	17.71	9.89	25.56	17.98	14.90	13.22	8.17	6.11	4.17
3/27/2000	7.86	18.78	20.27	14.04	13.65	13.90	9.34	5.82	4.20
4/3/2000	25.71	16.68	23.51	14.15	13.83	13.85	8.46	5.07	4.43
4/14/2000	42.50	12.49	26.94	15.62	15.02	15.67	7.44	3.61	3.22
4/18/2000	39.36	15.58	25.47	17.41	18.05	13.62	6.13	2.16	1.57
4/24/2000	25.07	15.26	24.50	14.29	14.43	16.56	8.40	3.89	2.67
5/5/2000	42.79	15.45	22.15	14.59	14.31	15.06	11.20	4.37	2.89
5/15/2000	7.00	11.65	19.78	17.49	17.71	12.16	8.68	5.28	7.25
6/7/2000	10.29	43.49	15.49	8.71	8.40	9.78	7.30	4.35	2.47
6/14/2000	5.29	39.52	19.88	7.59	7.11	8.94	7.91	5.13	3.90
6/21/2000	11.00	26.75	22.49	15.80	13.31	11.14	5.92	2.98	1.62
6/30/2000	14.29	32.31	25.91	13.68	10.72	8.63	4.72	2.24	1.79
7/7/2000	8.64	48.00	22.10	9.47	7.37	7.34	3.51	1.46	0.77
7/10/2000	4.00	25.67	24.96	12.29	9.28	11.99	9.80	4.40	1.61
7/21/2000	22.14	27.56	27.95	15.30	12.26	9.39	4.70	1.87	0.98
7/26/2000	29.79	14.98	37.22	14.20	11.26	11.79	6.45	2.69	1.42
8/4/2000	7.21	45.93	20.65	8.73	6.70	5.87	4.69	3.77	3.66
8/7/2000	3.36	30.30	15.89	9.70	10.30	12.60	10.63	6.72	3.87
8/14/2000	12.29	16.85	32.44	17.73	12.78	11.28	5.35	2.30	1.27
8/21/2000	10.29	33.87	23.16	12.28	10.33	9.5	6.43	3.03	1.38
8/29/2000	23.29	8.48	26.63	17.4	17.47	18.07	8.19	2.65	1.1
9/5/2000	5.86	25.61	20.46	11.57	12.88	13.95	9.35	4.28	1.89
9/12/2000	2.57	17.75	30.91	8.44	9.64	13.87	12.53	5.64	1.22
9/18/2000	10.00	43.36	23.19	10.58	10.72	4.64	4.7	1.92	0.88
9/25/2000	8.00	18.22	26.71	12.84	11.47	13.27	10.46	5.19	1.83

* not sieved due to caking while drying

sweeping period data

Table A5. Control site precipitation data

monitored event number	start date & time	end date & time	Total rainfall (in.)	Max. 15-min. intensity (in/hr)	Max. 30-min. intensity (in/hr)	Erosivity Index (hundreds of ft-lbs/acre * in/hr)	antecedent dry time (hrs)	comments
1	3/10/99 10:11	3/10/99 19:50	0.63	1.33	0.67	3.3	-	
1	3/11/99 2:16	3/11/99 18:09	0.25	0.26	0.2	0.3	-	
1	3/14/99 18:04	3/15/99 11:30	0.79	1.61	0.82	5.2	-	
	4/3/99 14:35	4/3/99 16:04	0.07	0.13	0.08	0	-	
	4/4/99 4:04	4/4/99 8:20	0.15	0.13	0.11	0.1	-	
	4/6/99 1:59	4/6/99 2:20	0.07	0.22	0.14	0.1	-	
	4/8/99 20:01	4/9/99 12:00	2.18	0.39	0.35	5.1	-	
2	4/11/99 6:48	4/11/99 14:13	0.26	0.36	0.26	0.4	42.80	
3	4/15/99 23:51	4/16/99 7:44	0.22	0.13	0.1	0.1	105.63	
	4/20/99 16:25	4/20/99 18:58	0.05	0.08	0.05	0	-	1
4	4/21/99 21:43	4/22/99 9:45	0.89	0.4	0.28	2.1	26.75	
	5/5/99 8:36	5/5/99 10:07	0.06	0.12	0.08	0	-	
	5/6/99 0:09	5/7/99 0:01	0.8	0.69	0.42	2.2	-	
	5/11/99 23:04	5/12/99 11:10	0.83	0.38	0.34	1.9	-	
	5/15/99 20:44	5/15/99 22:25	0.05	0.04	0.05	0	-	
	5/16/99 18:25	5/17/99 2:50	0.96	1.56	1.06	8.7	-	
	5/17/99 16:27	5/17/99 16:35	0.21	0.84	0.42	0.9	-	
	5/18/99 7:24	5/18/99 12:53	0.2	0.14	0.11	0.1	-	
5	5/21/99 17:56	5/21/99 21:48	0.15	0.19	0.15	0.1	77.05	
6	5/23/99 9:09	5/23/99 13:59	0.2	0.48	0.3	0.5	35.35	
	5/31/99 14:17	5/31/99 15:12	0.13	0.49	0.25	0.3	-	
	6/1/99 20:42	6/2/99 0:43	0.77	1.12	0.77	4.6	-	
	6/4/99 13:20	6/4/99 13:39	0.05	0.16	0.1	0	-	1
	6/6/99 17:06	6/7/99 4:03	0.4	0.53	0.28	0.8	-	
7	6/10/99 14:04	6/10/99 21:56	1.07	1.6	0.98	9.2	82.02	
	6/11/99 19:31	6/11/99 22:03	0.29	0.32	0.25	0.5	-	
	6/12/99 21:41	6/13/99 13:01	2.75	2.04	1.44	31	-	
8	6/16/99 17:15	6/16/99 18:41	0.13	0.2	0.16	0.1	76.23	
9	6/23/99 17:58	6/23/99 20:03	0.14	0.24	0.12	0.1	167.28	
10	6/28/99 16:19	6/28/99 19:02	0.75	1.96	1.09	7.6	116.27	
11	7/6/99 0:33	7/6/99 0:54	0.1	0.39	0.2	0.2	173.52	
12	7/9/99 0:10	7/9/99 2:01	2.14	2.92	2.54	54.36	71.27	
13	7/16/99 22:53	7/17/99 14:49	1.09	0.72	0.5	3.8	188.87	
	7/18/99 15:12	7/18/99 16:56	0.08	0.12	0.09	0	-	
	7/19/99 1:14	7/19/99 8:45	0.34	0.33	0.27	0.6	-	
14	7/21/99 0:02	7/21/99 10:06	1.51	2.8	1.68	24.2	39.28	
	7/23/99 16:23	7/23/99 17:48	0.08	0.16	0.11	0	-	
	7/26/99 6:09	7/26/99 8:44	0.07	0.13	0.07	0	-	
15	7/31/99 4:27	7/31/99 7:07	0.28	0.46	0.29	0.6	115.72	
16	8/7/99 8:51	8/7/99 11:21	0.32	0.4	0.32	0.7	169.73	
17	8/10/99 1:40	8/10/99 2:12	0.22	0.76	0.42	0.8	62.32	
	8/12/99 8:09	8/12/99 9:56	0.08	0.11	0.08	0	-	
18	8/18/99 21:27	8/19/99 4:08	0.58	0.48	0.36	1.3	155.52	
19	8/23/99 14:34	8/23/99 20:52	0.2	0.24	0.14	0.241	106.43	
	9/12/99 0:00	9/12/99 0:00	0.22	-	-	-	-	2

20	9/19/99 16:55	9/19/99 22:42	0.58	2.02	1.02	5.6	184.92	
21	9/27/99 1:18	9/27/99 6:10	0.13	0.12	0.08	0.088	170.60	
22	9/27/99 12:14	9/28/99 2:51	2.16	0.48	0.48	8.774	6.07	
	10/2/99 1:28	10/2/99 5:18	0.04	0.04	0.02	0	-	
23	10/3/99 11:05	10/3/99 20:21	0.54	0.24	0.18	0.819	29.78	
24	10/16/99 2:33	10/16/99 10:21	0.3	0.28	0.2	0.4	294.20	
25	11/10/99 17:29	11/10/99 19:52	0.5	0.92	0.53	2	607.13	
	11/19/99 6:48	11/19/99 7:16	0.04	0.11	0.08	0	-	
26	11/23/99 3:01	11/23/99 12:51	0.22	0.32	0.2	0.371	91.75	
27	11/23/99 16:56	11/23/99 17:18	0.12	0.4	-	-	4.08	
	12/3/99 9:15	12/3/99 14:40	0.16	0.15	0.09	0.1	-	
	12/4/99 18:37	12/5/99 9:37	0.64	0.18	0.15	0.5	-	
	12/9/99 15:38	12/9/99 19:59	0.15	0.09	0.07	0	-	
28	12/14/99 15:37	12/15/99 11:51	0.24	0.09	0.06	0.1	115.63	
	12/19/99 23:57	12/20/99 2:54	0.06	0.04	0.05	0	-	
	1/2/00 2:42	1/2/00 5:11	0.1	0.2	0.14	0.1	-	
29	1/3/00 12:40	1/3/00 14:56	0.04	0.04	0.02	0	-	1
	1/6/00 10:49	1/6/00 15:33	0.28	0.14	0.12	0.2	-	
	1/8/00 10:39	1/8/00 13:48	0.12	0.09	0.07	0	-	
	1/9/00 21:07	1/10/00 8:28	0.13	0.04	0.05	0	-	
	1/15/00 10:48	1/15/00 14:17	0.06	0.08	0.06	0	-	
	1/30/00 0:00	-	-	-	-	-	-	
	2/3/00 13:18	2/3/00 16:29	0.06	0.04	0.04	0	-	
	2/5/00 12:45	2/5/00 14:44	0.05	0.04	0.05	0	-	
	2/13/00 12:50	2/13/00 15:34	0.06	0.09	0.06	0	-	1
	2/14/00 10:21	2/14/00 16:28	0.2	0.1	0.08	0.1	-	1
	2/15/00 13:46	2/16/00 8:55	108.85	48	42	2910	-	
	2/17/00 19:57	2/18/00 3:49	0.65	0.53	0.36	1.7	-	
30	2/19/00 12:02	2/19/00 17:24	0.05	0.04	0.04	0	-	1
	2/20/00 10:34	2/20/00 21:22	0.24	0.1	0.07	0.1	-	1
31	2/21/00 8:14	2/21/00 18:46	0.09	0.1	0.08	0	-	1
32	2/24/00 4:17	2/24/00 9:29	0.35	0.19	0.17	0.3	-	1
	3/1/00 2:25	3/1/00 6:24	0.05	0.08	0.04	0	-	
	3/8/00 19:00	3/8/00 22:43	0.09	0.1	0.06	0	-	
	3/9/00 6:07	3/9/00 9:22	0.07	0.12	0.07	0	-	1
	3/20/00 5:42	3/21/00 4:56	1.76	5.72	2.96	42	-	
	3/24/00 11:56	3/24/00 13:32	0.16	0.28	0.15	0.2	-	
	3/28/00 15:13	3/28/00 16:54	0.06	0.12	0.08	0	-	
33	4/7/00 7:53	4/7/00 17:40	0.27	0.15	0.12	0.1	-	
	4/8/00 8:49	4/8/00 15:20	0.33	0.13	0.1	0.2	-	
	4/11/00 5:08	4/11/00 10:22	0.11	0.04	0.05	0	-	
	4/19/00 2:41	4/20/00 9:41	1.55	0.88	0.55	6.1	-	
	4/20/00 17:41	4/21/00 5:22	0.25	0.13	0.1	0.1	-	
	4/23/00 3:19	4/23/00 7:21	0.26	0.26	0.19	0.3	-	
	4/29/00 0:38	4/29/00 1:52	0.05	0.08	0.06	0	-	1
	5/1/00 3:41	5/1/00 8:46	0.1	0.1	0.07	0	-	
	5/8/00 9:31	5/8/00 9:38	0.05	0.2	0.1	0	-	
	5/8/00 19:59	5/9/00 0:28	0.19	0.64	0.32	0.5	-	
34	5/9/00 10:44	5/9/00 17:58	0.8	0.28	0.22	1.1	10.27	
	5/11/00 10:17	5/11/00 14:30	0.05	0.12	0.06	0	-	1
	5/12/00 0:36	5/12/00 1:35	0.71	1.76	1.38	9.4	-	
	5/16/00 2:36	5/16/00 8:48	0.06	0.04	0.05	0	-	

35	5/17/00 17:26	-	1.7	-	-	-	32.63	2
	5/18/00 11:09	-	1.53	-	-	-	-	2
	5/27/00 2:37	5/28/00 13:58	0.91	0.4	0.29	1.5	-	
	5/29/00 9:49	5/30/00 10:31	0.8	0.64	0.36	1.8	-	
	5/31/00 6:32	5/31/00 15:06	0.52	0.42	0.36	1.3	-	
36	6/1/00 19:48	6/1/00 22:07	0.38	1.11	0.62	2.1	28.70	
37	6/4/00 13:13	6/5/00 6:09	0.46	0.26	0.23	0.6	63.10	
	6/11/00 1:16	6/11/00 4:35	0.06	0.11	0.08	0	-	
	6/12/00 7:31	6/13/00 1:58	0.93	0.35	0.3	1.7	-	
	6/13/00 18:58	6/13/00 20:32	0.09	0.22	0.13	0.1	-	
38	6/14/00 16:14	6/14/00 16:31	0.33	1.28	0.66	2.2	19.70	
39	6/20/00 7:28	6/20/00 10:21	0.24	0.76	0.4	0.8	134.95	
	6/23/00 21:59	6/23/00 22:14	0.05	0.2	0.1	0	-	
	6/28/00 10:34	6/28/00 14:37	0.2	0.2	0.13	0.1	-	
	7/2/00 18:06	7/3/00 3:58	4.4	4.56	3	108.4	-	
	7/8/00 8:15	7/8/00 9:21	0.49	1.16	0.85	3.6	-	
	7/10/00 5:47	7/10/00 8:27	0.35	0.38	0.32	0.7	-	
	7/14/00 1:17	7/14/00 1:47	0.12	0.37	0.24	0.2	-	
	7/14/00 17:30	7/14/00 17:36	0.04	0.16	0.08	0	-	
	7/20/00 17:39	7/20/00 19:14	0.05	0.17	0.09	0	-	1
	7/25/00 12:14	7/25/00 12:35	2.02	6.97	4.04	54	-	
	7/27/00 4:34	7/27/00 5:20	0.89	2.45	1.32	11.7	-	
40	7/28/00 12:19	7/28/00 13:55	1.74	2.2	1.7	28.79	30.98	
	7/29/00 1:28	7/29/00 4:59	0.35	1.24	0.66	2.1	-	
	7/31/00 0:02	7/31/00 20:31	0.32	0.31	0.26	0.4	-	
	8/2/00 14:11	8/2/00 14:36	0.11	0.29	0.22	0.2	-	
41	8/5/00 13:26	8/5/00 21:30	2.61	2.08	1.42	32.9	70.83	
	8/13/00 11:52	8/13/00 12:18	0.05	0.14	0.1	0	-	
42	8/17/00 3:59	8/17/00 10:39	2.17	1.4	1.12	20.1	87.68	
43	8/17/00 20:50	8/17/00 23:52	0.07	0.09	0.06	0	10.18	
	8/22/00 16:53	8/22/00 19:52	0.14	0.17	0.12	0.1	-	
44	8/26/00 9:58	8/26/00 11:00	0.84	2.84	1.59	13.3	86.10	
	9/2/00 5:46	9/2/00 11:06	0.59	1.38	0.72	3.7	-	
	9/3/00 7:38	9/3/00 10:16	0.28	0.54	0.29	0.6	-	
45	9/7/00 23:24	9/8/00 6:01	0.27	0.4	0.21	0.4	109.13	
46	9/10/00 7:57	9/10/00 9:02	0.48	1.12	0.8	3.5	49.93	
	9/11/00 10:37	9/12/00 4:12	2.67	1.72	1.5	34.5	-	
47	9/14/00 1:28	9/14/00 8:17	0.84	0.73	0.46	2.7	45.27	
48	9/19/00 20:21	9/20/00 13:45	0.47	0.16	0.1	0.2	132.07	
	9/22/00 10:50	9/23/00 2:32	2.29	2.04	1.38	29.36	45.08	

shaded cells mean at least some snow melt so precipitation data may not be valid

comments

1 data from the test site

2 data from Mitchell International Airport

Table A6. Test site precipitation data

monitored event number	start date & time	end date & time	Total rainfall (in.)	Max. 15-min. intensity (in/hr)	Max. 30-min. intensity (in/hr)	Erosivity Index (hundreds of ft-lbs/acre * in/hr)	antecedent dry time (hrs)	comments
1	3/10/99 8:53	3/10/99 16:55	0.45	0.15	0.12	0.3	-	
1	3/11/99 9:44	3/11/99 14:27	0.14	0.08	0.06	0	-	
	3/31/99 11:25	3/31/99 12:21	1.87	2.36	2.24	42.5	-	
	4/6/99 1:59	4/6/99 2:19	0.07	0.24	0.14	0.1	-	
	4/8/99 20:02	4/9/99 12:13	2.42	0.41	0.36	5.9	-	
2	4/11/99 6:51	4/11/99 14:22	0.26	0.37	0.25	0.4	42.633	
3	4/15/99 22:23	4/16/99 7:26	0.26	0.13	0.11	0.1	104.017	
	4/20/99 16:25	4/20/99 18:58	0.05	0.08	0.05	0	-	
4	4/21/99 21:43	4/22/99 9:20	0.95	0.44	0.32	2.561	26.75	
	4/22/99 14:18	4/22/99 15:57	0.19	0.28	0.26	0.416	-	
	4/22/99 19:29	4/22/99 23:56	0.46	0.4	0.34	1.318	-	
	5/5/99 8:37	5/5/99 9:49	0.06	0.12	0.08	0	-	
	5/5/99 23:47	5/7/99 0:01	0.85	0.69	0.42	2.3	-	
	5/11/99 22:58	5/12/99 11:09	0.89	0.42	0.36	2.2	-	
	5/13/99 6:02	5/13/99 6:22	0.04	0.14	0.08	0	-	
	5/15/99 20:43	5/15/99 22:52	0.05	0.04	0.05	0	-	
	5/16/99 18:26	5/17/99 2:47	1.02	1.44	0.95	8.4	-	
	5/17/99 12:59	5/17/99 16:36	0.26	1	0.5	1.2	-	
	5/18/99 7:29	5/18/99 12:51	0.30	0.24	0.14	0.2	-	
5	5/21/99 17:56	5/21/99 21:47	0.17	0.22	0.18	0.2	77.083	
6	5/23/99 9:09	5/23/99 14:09	0.50	1.32	0.66	3	35.367	
	5/31/99 14:18	5/31/99 15:12	0.15	0.57	0.29	0.4	-	
	6/1/99 20:43	6/2/99 0:26	0.87	1.32	0.88	6.1	-	
	6/4/99 13:20	6/4/99 13:39	0.05	0.16	0.1	0	-	
	6/6/99 17:09	6/7/99 4:24	0.54	0.6	0.36	1.5	-	
7	6/10/99 14:01	6/10/99 22:01	1.17	1.68	1.04	10.6	81.617	
	6/11/99 19:31	6/11/99 22:48	0.31	0.35	0.27	0.6	-	
	6/12/99 21:34	6/13/99 13:07	3.29	2.52	1.78	47.6	-	
8	6/16/99 17:16	6/16/99 18:28	0.16	0.26	0.22	0.2	76.15	
9	6/23/99 18:00	6/23/99 20:03	0.15	0.28	0.14	0.1	167.533	
10	6/28/99 16:41	6/28/99 19:02	0.83	2.14	1.2	9.4	116.633	
11	7/6/99 0:34	7/6/99 0:38	0.09	0.36	0.18	0.2	173.533	
12	7/9/99 0:10	7/9/99 2:01	2.45	3.08	2.7	63.003	71.533	
13	7/16/99 22:52	7/17/99 15:16	1.26	0.68	0.56	5	188.85	
	7/18/99 15:11	7/18/99 17:00	0.09	0.13	0.09	0	-	
	7/19/99 1:12	7/19/99 8:46	0.40	0.32	0.28	0.7	-	
14	7/20/99 23:31	7/21/99 9:43	1.85	3.24	1.93	34.6	38.75	
	7/23/99 16:29	7/23/99 17:51	0.08	0.18	0.12	0.1	-	
	7/26/99 6:07	7/26/99 9:02	0.08	0.12	0.07	0	-	
15	7/31/99 4:28	7/31/99 7:12	0.31	0.5	0.33	0.7	115.433	
16	8/7/99 8:51	8/7/99 11:21	0.32	0.4	0.32	0.7	169.65	1
17	8/10/99 1:40	8/10/99 2:12	0.22	0.76	0.42	0.8	62.317	1
	8/12/99 8:02	8/12/99 9:51	0.08	0.11	0.08	0	-	
18	8/18/99 20:36	8/19/99 3:54	0.55	0.37	0.29	1	154.75	
19	8/23/99 14:27	8/23/99 20:37	0.24	0.4	0.2	0.427	106.55	
	9/12/99 0:00		0.22	-	-	-	-	2
20	9/19/99 17:00	9/19/99 22:50	0.50	1.74	0.88	4.1	185	

21	9/27/99 1:58	9/27/99 6:14	0.13	0.12	0.08	0.088	171.133	
22	9/27/99 9:23	9/28/99 2:49	2.36	0.56	0.48	9.592	3.15	
	10/2/99 1:18	10/2/99 6:27	0.05	0.04	0.02	0	-	
23	10/3/99 11:16	10/3/99 20:24	0.57	0.28	0.2	0.965	28.817	
24	10/16/99 2:33	10/16/99 10:38	0.29	0.21	0.18	0.3	294.15	
25	11/10/99 17:29	11/10/99 20:00	0.49	0.85	0.48	1.8	606.85	
	11/19/99 6:49	11/19/99 7:19	0.04	0.1	0.08	0	-	
26	11/23/99 3:00	11/23/99 12:50	0.21	0.32	0.18	0.318	91.683	
27	11/23/99 16:52	11/23/99 17:26	0.12	0.36	0.22	0.227	4.033	
	12/3/99 9:15	12/3/99 14:40	0.15	0.14	0.09	0.1	-	
	12/4/99 19:09	12/5/99 9:56	0.63	0.18	0.14	0.5	-	
	12/9/99 15:46	12/9/99 19:11	0.13	0.09	0.07	0	-	
28	12/14/99 15:00	12/15/99 20:02	0.28	0.1	0.07	0.1	115.817	
	12/19/99 23:05	12/20/99 4:53	0.06	0.04	0.05	0	-	
	1/2/00 2:13	1/2/00 3:29	0.09	0.18	0.14	0.1	-	
29	1/3/00 12:40	1/3/00 14:56	0.04	0.04	0.02	0	-	
	1/6/00 11:00	1/6/00 15:45	0.34	0.17	0.15	0.3	-	
	1/9/00 21:26	1/10/00 8:26	0.12	0.04	0.05	0	-	
	1/15/00 10:48	1/15/00 14:17	0.06	0.08	0.06	0	-	1
	1/30/00 0:00	-	0.21	-	-	-	-	2
	2/13/00 12:50	2/13/00 15:34	0.06	0.09	0.06	0	-	
	2/14/00 10:21	2/14/00 16:28	0.20	0.1	0.08	0.1	-	
	2/15/00 11:46	2/15/00 18:36	0.19	0.09	0.07	0.1	-	
	2/17/00 19:57	2/18/00 3:49	0.65	0.53	0.36	1.7	-	1
30	2/19/00 12:48	2/19/00 15:45	0.05	0.04	0.04	0	-	
	2/20/00 10:30	2/20/00 16:40	0.24	0.1	0.07	0.1	-	
31	2/21/00 9:41	2/21/00 12:03	0.09	0.1	0.08	0	-	
32	2/24/00 4:17	2/24/00 9:33	0.35	0.19	0.17	0.3	-	
	3/1/00 2:25	3/1/00 6:24	0.05	0.08	0.04	0	-	1
	3/8/00 17:48	3/8/00 19:49	0.22	0.52	0.3	0.5	-	
	3/9/00 6:07	3/9/00 9:22	0.07	0.12	0.07	0	-	
	3/19/00 6:56	3/21/00 4:56	0.78	0.17	0.11	0.4	-	
	3/24/00 11:56	3/24/00 13:32	0.17	0.28	0.15	0.2	-	
	3/28/00 15:15	3/28/00 17:01	0.08	0.14	0.1	0	-	
33	4/7/00 7:52	4/7/00 17:13	0.27	0.16	0.12	0.1	-	
	4/8/00 11:05	4/8/00 17:02	0.71	0.43	0.26	1.2	-	
	4/11/00 6:05	4/11/00 13:28	0.12	0.04	0.05	0	-	
	4/16/00 21:36	4/16/00 23:38	0.04	0.08	0.05	0	-	
	4/19/00 2:41	4/20/00 9:41	1.55	0.88	0.55	6.1	-	1
	4/20/00 17:41	4/21/00 5:22	0.25	0.13	0.1	0.1	-	1
	4/23/00 3:15	4/23/00 6:43	0.29	0.3	0.21	0.4	-	
	4/29/00 0:38	4/29/00 1:52	0.05	0.08	0.06	0	-	
	5/1/00 3:38	5/1/00 8:43	0.11	0.1	0.08	0	-	
	5/8/00 16:51	5/9/00 1:33	0.28	0.92	0.46	1	-	2
34	5/9/00 10:50	5/9/00 18:00	1.13	0.43	0.3	2.3	9.283	
	5/11/00 10:17	5/11/00 14:30	0.05	0.12	0.06	0	-	
	5/12/00 0:36	5/12/00 1:35	0.71	1.76	1.38	9.4	-	1
	5/16/00 4:15	5/16/00 8:51	0.09	0.1	0.07	0	-	
35	5/17/00 14:22	-	1.70	-	-	-	29.517	2
	5/18/00 11:09	-	1.53	-	-	-	-	2
	5/27/00 2:37	5/28/00 13:58	0.91	0.4	0.29	1.5	-	1
	5/29/00 9:49	5/30/00 10:31	0.80	0.64	0.36	1.8	-	1

	5/31/00 6:32	5/31/00 15:06	0.52	0.42	0.36	1.3	-	1
36	6/1/00 19:48	6/1/00 22:07	0.38	1.11	0.62	2.1	28.7	1
37	6/4/00 13:05	6/5/00 6:09	0.46	0.26	0.23	0.6	62.967	1
	6/11/00 1:16	6/11/00 1:59	0.05	0.11	0.08	0	-	
	6/12/00 5:23	6/13/00 2:47	0.96	0.34	0.31	1.7	-	
	6/13/00 18:59	6/13/00 22:22	0.09	0.2	0.11	0.1	-	
38	6/14/00 16:16	6/14/00 16:27	0.36	1.44	0.72	2.7	17.9	
39	6/20/00 7:27	6/20/00 9:13	0.21	0.64	0.34	0.635	135	
	6/23/00 21:59	6/23/00 22:33	0.07	0.25	0.14	0.1	-	
	6/28/00 10:34	6/28/00 14:37	0.20	0.2	0.13	0.1	-	1
	7/2/00 18:06	7/3/00 3:58	4.40	4.56	3	108.4	-	1
	7/8/00 8:15	7/8/00 8:44	0.31	1.04	0.62	1.7	-	
	7/10/00 5:45	7/10/00 8:20	0.34	0.36	0.3	0.7	-	
	7/14/00 1:17	7/14/00 1:50	0.15	0.46	0.29	0.3	-	
	7/14/00 17:30	7/14/00 17:36	0.04	0.16	0.08	0	-	1
	7/20/00 17:39	7/20/00 19:14	0.05	0.17	0.09	0	-	
	7/25/00 11:12	7/25/00 11:58	2.02	3.51	2.8	53.5	-	
	7/27/00 4:34	7/27/00 5:20	0.89	2.45	1.32	11.7	-	1
40	7/28/00 12:19	7/28/00 13:55	1.74	2.2	1.7	28.786	30.983	1
	7/29/00 1:28	7/29/00 4:50	0.24	0.76	0.38	0.8	-	
	7/31/00 0:03	7/31/00 21:05	0.38	0.32	0.26	0.5	-	
	8/2/00 14:13	8/2/00 14:37	0.11	0.31	0.22	0.2	-	
41	8/5/00 13:30	8/5/00 21:30	2.61	2.08	1.42	32.9	70.883	1
	8/13/00 12:00	8/13/00 12:34	0.04	0.12	0.08	0	-	
42	8/17/00 4:02	8/17/00 10:39	2.17	1.4	1.12	20.1	87.467	1
43	8/17/00 21:03	8/18/00 5:39	0.06	0.04	0.04	0	10.4	
	8/22/00 16:59	8/22/00 19:49	0.11	0.16	0.09	0.1	-	
44	8/26/00 10:04	8/26/00 11:00	0.84	2.84	1.59	13.3	86.25	1
	9/2/00 5:46	9/2/00 11:06	0.59	1.38	0.72	3.7	-	1
	9/3/00 7:38	9/3/00 10:16	0.28	0.54	0.29	0.6	-	1
45	9/7/00 23:25	9/8/00 5:57	0.21	0.32	0.2	0.3	109.15	
46	9/10/00 7:57	9/10/00 9:02	0.48	1.12	0.8	3.5	50	1
	9/11/00 10:38	9/12/00 4:12	2.67	1.72	1.5	34.5	-	1
47	9/14/00 1:28	9/14/00 8:14	0.86	0.76	0.48	2.9	45.267	
48	9/19/00 20:25	9/20/00 13:45	0.42	0.16	0.1	0.2	132.183	
OKM-11	9/22/00 10:59	9/22/00 19:27	0.89	0.36	0.36	2.707	45.233	

shaded cells mean at least some snow melt so precipitation data may not be valid

comments

1 data from the control site

2 data from Mitchell International Airport

Table A7. Runoff concentrations from test site

Event	Date	COD (mg/L)	Total Solids (mg/L)	TSS (mg/L)	S. Sed (mg/L)	Diss. NH3 (mg/L)	Total NH3 + org. N (mg/L)	Diss. NO2+NO3 (mg/L)	Total P (mg/L)	Diss. Ortho-P (mg/L)	Total Ca (mg/L)	Total Mg (mg/L)	Diss. Cl (mg/L)	Diss. Cu (ug/L)	Diss Zn (ug/L)	Total Zn (ug/L)	Total Cd (ug/L)	Total Pb (ug/L)	Total Cu (ug/L)	Total Hardness (mg/L)
1	3/11/1999	-	-	182	171	-	-	-	-	-	-	-	3370	-	-	488	-	-	120	-
2	4/11/1999	70	1570	88		0.923	1.87	2.16	0.105	0.023	47	12	791	20	47	200	1.2	29	61	170
3	4/16/1999	-	-	84	117	-	-	-	-	-	-	-	417	-	-	240	-	-	69	-
4	4/21/1999	-	-	61		-	-	-	-	-	-	-	-	-	-	170	-	-	64	-
5	5/21/1999	-	-	180		-	-	-	-	-	-	-	138	-	-	320	-	-	88	-
6	5/23/1999	-	-	352	2330	-	-	-	-	-	-	-	65.1	-	-	290	-	-	100	-
7	6/10/1999	74	-	689	3090	0.481	1.79	1.03	0.249	0.013	510	270	40.9	12	28	710	3.3	130	1700	2400
8	6/16/1999	-	-	127	137	-	-	-	-	-	-	-	-	-	-	290	-	-	58	-
9	6/23/1999	-	-	286	388	-	-	-	-	-	-	-	-	-	-	570	-	-	120	-
10	6/28/1999	-	-	236	2930	-	-	-	-	-	-	-	17.5	-	-	350	-	-	68	-
11	7/6/1999	-	-	214	362	-	-	-	-	-	-	-	-	-	-	460	-	-	110	-
12	7/9/1999	-	-	230	2760	-	-	-	-	-	-	-	-	-	-	260	-	-	72	-
rep.		-	-	569		-	-	-	-	-	-	-	-	-	-	950	-	-	140	-
13	7/16/1999	61	208	159	312	0.311	1.55	0.66	0.138	0.12	27	10	29.3	14	43	200	0.64	20	50	110
rep.		70	350	98		0.312	1.05	0.649	0.126	0.12	27	9.4	29.5	14	39	150	0.5	21	41	110
14	7/21/1999	-	-	367	981	-	-	-	-	-	-	-	-	-	-	330	-	-	77	-
15	7/31/1999	78	354	335	485	0.407	1.54	0.629	0.256	0.064	44	16	30	17	12	310	0.81	35	71	180
16	8/7/1999	-	-	284	607	-	-	-	-	-	-	-	24.5	-	-	530	-	-	69	-
17	8/10/1999	-	-	670	2170	-	-	-	-	-	-	-	-	-	-	480	-	-	45	-
18	8/18/1999	-	-	87	214	-	-	-	-	-	-	-	-	-	-	150	-	-	34	-
19	8/23/1999	-	-	394	691	-	-	-	-	-	-	-	-	-	-	370	-	-	72	-
20	9/19/1999	-	-	410	2730	-	-	-	-	-	-	-	-	-	-	590	-	-	170	-
21	9/27/1999	-	-	84	78	-	-	-	-	-	-	-	39.5	-	-	190	-	-	53	-
22	9/27/1999	39	276	77	588	0.26	0.71	0.309	0.15	0.019	39	17	15.8	5.8	15	170	0.55	35	48	170
23	10/3/1999	-	-	83	91	-	-	-	-	-	-	-	31.8	-	-	160	-	-	31	-
24	10/16/1999	-	-	162	27	-	-	-	-	-	-	-	-	-	-	270	-	-	56	-
25	11/10/1999	-	-	208	250	-	-	-	-	-	-	-	-	-	-	310	-	-	60	-
26	11/19/1999	-	-	158	200	-	-	-	-	-	-	-	-	-	-	290	-	-	71	-
rep.	11/19/1999	-	-	-	174	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	11/23/1999	-	-	416	351	-	-	-	-	-	-	-	-	-	-	370	-	-	100	-
rep.	11/23/1999	-	-	-	357		-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	12/14/1999	-	-	82	243	-	-	-	-	-	-	-	-	-	-	240	-	-	62	-
rep.	12/14/1999	-	-	-	117		-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	1/3/2000	-	-	43	166	-	-	-	-	-	-	-	9840	-	-	280	-	-	47	-
30	2/18/2000	-	-	78	71	-	-	-	-	-	-	-	-	-	-	480	-	-	49	-
31	2/21/2000	120	5104	154	162	0.852	0.98	0.659	0.335	0.091	100	20	2730	130	440	440	2.3	46	130	330
rep.	2/21/2000	-	-	152	162	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	2/24/2000	430	3930	756	1138	0.623	1.77	0.91	0.763	0.027	180	63	1690	420	1500	1500	6.7	250	420	700
rep.	2/24/2000	-	-	-	552		-	-	-	-	-	-	-	-	-	-	-	-	-	-
33	4/7/2000	97	3090	113	690.4	1.12	2.33	0.793	0.092	0.01	42	9.4	1750	16	64	340	1.6	38	74	140
rep.	4/7/2000	-	-	150	193	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	5/9/2000	-	-	185	989	-	-	-	-	-	-	-	-	-	-	380	-	-	140	-
rep.	5/9/2000	-	-	244	722.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
35	5/17/2000	-	-	99	229	-	-	-	-	-	-	-	49.8	-	-	230	-	-	61	-
rep.	5/17/2000	-	-	-	387		-	-	-	-	-	-	-	-	-	-	-	-	-	-

36	6/1/2000	-	-	201	1070	-	-	-	-	-	-	-	-	-	-	520	-	-	85	-
rep.		-	-	-	621.7		-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	6/4/2000	-	-	36	74.1	-	-	-	-	-	-	-	-	-	-	80	-	-	25	-
rep.		-	-	-	37.1		-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	6/14/2000	-	-	398	858.0	-	-	-	-	-	-	-	-	-	-	550	-	-	58	-
39	6/20/2000	-	-	86	242.9	-	-	-	-	-	-	-	-	-	-	280	-	-	68	-
40	7/28/2000	36	870	1230	2155.3	0.249	1.08	0.408	0.281	0.006	400	200	7.2	6.1	15	1200	2.2	210	180	1800
41	8/5/2000	-	-	141	209.0	-	-	-	-	-	-	-	-	-	-	200	-	-	84	-
rep.		-	-	-	230.2		-	-	-	-	-	-	-	-	-	-	-	-	-	-
42	8/17/2000	-	-	200	216	-	-	-	-	-	-	-	-	-	-	320	-	-	71	-
43	8/17/2000	-	-	9.5	169	-	-	-	-	-	-	-	-	-	-	99	-	-	30	-
rep.		-	-	-	51.0		-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	8/26/2000	51	236	134	203.7	0.67	1.71	0.794	0.266	0.114	27	12	19	8.9	25	200	0.55	51	39	120
rep.	8/26/2000	-	-	65	187	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	9/7/2000	-	-	245	192	-	-	-	-	-	-	-	66.6	-	-	340	-	-	68	-
rep.	9/7/2000	-	-	193	234	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
46	9/10/2000	50	204	115	242.2	0.359	0.9	0.415	0.152	0.034	20	9	16.3	7.3	21	140	0.48	18	40	87
rep.	9/10/2000	-	-	280	310	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	9/14/2000	-	-	40	34.7	-	-	-	-	-	-	-	-	-	-	130	-	-	26	-
rep.		-	-	-	42		-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	9/19/2000	-	-	95		-	-	-	-	-	-	-	-	-	-	230	-	-	50	-

rep. - replicate sample
Dis. - Dissolved
COD - Chemical Oxygen Demand
TSS - Total Suspended Residue
S.Sed. - Total Suspended Sediment
NH3 - ammonia
org. N - organic nitrogen
NO2 + NO3 - nitrate + nitrite
P - phosphorus
Ca - Calcium
Mg - magnesium
Cl - chloride
Cu - copper
Zn - zinc
Cd - cadmium
Pb - lead

shaded areas are sweeping period data

Table A8. Runoff Concentrations From Control Site

Table A8. Runoff concentrations from control site

Event	Date	COD (mg/L)	Total Solids (mg/L)	TSS (mg/L)	S. Sed (mg/L)	Diss. NH3 (mg/L)	Total NH3 + Total NH3 + org. N (mg/L)	Diss. NO2+NO3 (mg/L)	Total P (mg/L)	Diss. Ortho-P (mg/L)	Total Ca (mg/L)	Total Mg (mg/L)	Diss. Cl (mg/L)	Diss. Cu (ug/L)	Diss Zn (ug/L)	Total Zn (ug/L)	Total Cd (ug/L)	Total Pb (ug/L)	Total Cu (ug/L)	Total Hardness (mg/L)
1	3/11/1999	-	-	50	69	-	-	-	-	-	-	-	5180	-	-	254.1	-	-	49	-
2	4/11/1999	64	1140	104	-	0.627	1.4	1.72	0.113	0.022	69	28	466	18	39	180	0.75	30	54	290
3	4/16/1999	-	-	86	122	-	-	-	-	-	-	-	256	-	-	200	-	-	61	-
4	4/21/1999	-	-	284	-	-	-	-	-	-	-	-	-	-	-	480	-	-	150	-
5	5/21/1999	-	-	224	-	-	-	-	-	-	-	-	117	-	-	290	-	-	80	-
6	5/23/1999	-	-	277	1130	-	-	-	-	-	-	-	45.5	-	-	420	-	-	170	-
7	6/10/1999	140	2580	613	866	0.346	1.31	0.9	0.259	0.011	450	240	23.2	13	31	390	1.8	110	160	2100
8	6/16/1999	-	-	108	114	-	-	-	-	-	-	-	-	-	-	220	-	-	66	-
9	6/23/1999	-	-	130	158	-	-	-	-	-	-	-	-	-	-	280	-	-	82	-
10	6/28/1999	-	-	447	711	-	-	-	-	-	-	-	32.8	-	-	500	-	-	140	-
11	7/6/1999	-	-	280	361	-	-	-	-	-	-	-	-	-	-	520	-	-	140	-
12	7/9/1999	-	-	232	968	-	-	-	-	-	-	-	-	-	-	230	-	-	66	-
rep.		-	-	145	-	-	-	-	-	-	-	-	-	-	-	210	-	-	77	-
13	7/16/1999	60	232	106	377	0.206	1.01	0.582	0.144	0.009	33	13	23.6	14	34	170	0.56	19	39	140
rep.		61	246	131	-	0.206	0.33	0.565	0.15	0.01	34	14	23.5	14	33	150	0.64	19	41	140
14	7/21/1999	-	-	218	487	-	-	-	-	-	-	-	-	-	-	180	-	-	66	-
15	7/31/1999	120	934	256	346	0.026	1.87	0.825	0.321	0.004	49	21	56.4	22	57	550	2	60	88	210
16	8/7/1999	-	-	236	1670	-	-	-	-	-	-	-	30	-	-	340	-	-	88	-
17	8/10/1999	-	-	130	189	-	-	-	-	-	-	-	-	-	-	180	-	-	41	-
18	8/18/1999	-	-	145	353	-	-	-	-	-	-	-	-	-	-	140	-	-	35	-
19	8/23/1999	-	-	87	106	-	-	-	-	-	-	-	-	-	-	200	-	-	53	-
20	9/19/1999	-	-	204	1080	-	-	-	-	-	-	-	-	-	-	270	-	-	68	-
21	9/27/1999	-	-	89	95	-	-	-	-	-	-	-	48.6	-	-	220	-	-	69	-
22	9/27/1999	53	152	91	306	0.327	0.88	0.299	0.102	0.019	30	14	15.1	7.0	21	140	0.46	26	36	130
23	10/3/1999	-	-	33	32	-	-	-	-	-	-	-	37.8	-	-	110	-	-	24	-
24	10/16/1999	-	-	124	12	-	-	-	-	-	-	-	31.1	-	-	240	-	-	93	-
25	11/10/1999	-	-	180	231	-	-	-	-	-	-	-	-	-	-	320	-	-	73	-
rep.		-	-	-	425	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
26	11/19/1999	-	-	140	109	-	-	-	-	-	-	-	-	-	-	270	-	-	81	-
rep.		-	-	-	162	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	11/23/1999	-	-	184	186	-	-	-	-	-	-	-	-	-	-	310	-	-	78	-
rep.		-	-	-	181	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
28	12/14/1999	-	-	124	179	-	-	-	-	-	-	-	-	-	-	250	-	-	65	-
rep.		-	-	-	106	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	1/3/2000	-	-	128	180	-	-	-	-	-	-	-	13000	-	-	580	-	-	120	-
30	2/18/2000	-	-	89	59	-	-	-	-	-	-	-	-	-	-	470	-	-	77	-
rep.		-	-	-	84	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
31	2/21/2000	84	3530	90	91	0.798	0.93	0.758	0.173	0.027	110	27	1860	82	290	290	1.2	42	82	370
rep.	-	-	-	84	94	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
32	2/24/2000	370	4398	734	689	0.806	1.95	1.17	0.678	0.011	160	52	1970	620	1500	1500	6.1	240	620	620
33	4/7/2000	110	3270	112	450	1.07	2.15	0.741	0.199	0.005	45	9.8	1770	18	110	360	2	41	81	150
rep.		-	-	126	167	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
34	5/9/2000	-	-	108	152	-	-	-	-	-	-	-	-	-	-	240	-	-	69	-
rep.		-	-	124	97	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

35	5/17/2000	-	-	89	348	-	-	-	-	-	-	-	36.7	-	-	180	-	-	73	-
rep.		-	-	-	246	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
36	6/1/2000	-	-	102	165	-	-	-	-	-	-	-	-	-	-	170	-	-	59	-
rep.		-	-	-	215	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
37	6/4/2000	-	-	26	32	-	-	-	-	-	-	-	-	-	-	79	-	-	25	-
rep.		-	-	-	29	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
38	6/14/2000	-	-	213	330.3	-	-	-	-	-	-	-	-	-	-	500	-	-	58	-
39	6/20/2000	-	-	139	200.8	-	-	-	-	-	-	-	-	-	-	250	-	-	65	-
40	7/28/2000	41	176	134	325	0.481	1.19	0.457	0.13	0.03	15	6.3	9.4	7.4	21	180	0.58	31	46	64
rep.		-	-	-	122.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
41	8/5/2000	-	-	99	258.5	-	-	-	-	-	-	-	-	-	-	180	-	-	66	-
42	8/17/2000	-	-	87	80	-	-	-	-	-	-	-	-	-	-	210	-	-	63	-
43	8/17/2000	-	-	11	48	-	-	-	-	-	-	-	-	-	-	63	-	-	20	-
rep.		-	-	-	135.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
44	8/26/2000	42	132	62	73.3	0.597	1.8	0.703	0.13	0.047	13	5.3	15.2	8.9	28	120	0.49	19	36	55
rep.		-	-	120	68	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
45	9/7/2000	-	-	-	114	-	-	-	-	-	-	-	35.8	-	-		-	-		-
46	9/10/2000	45	130	69	88.8	0.359	1.15	0.501	0.213	0.039	29	13	11.5	8	18	190	0.45	22	37	130
rep.		-	-	73	92	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
47	9/14/2000	-	-	55	62.7	-	-	-	-	-	-	-	-	-	-	110	-	-	26	-
rep.		-	-	-	48	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
48	9/19/2000	-	-	66	-	-	-	-	-	-	-	-	-	-	-	170	-	-	39	-

Rep. - replicate sample
Dis. - Dissolved
COD - Chemical Oxygen Demand
TSS - Total Suspended Residue
S.Sed. - Total Suspended Sediment
NH3 - ammonia
org. N - organic nitrogen
NO2 + NO3 - nitrate + nitrite
P - phosphorus
Ca - Calcium
Mg - magnesium
Cl - chloride
Cu - copper
Zn - zinc
Cd - cadmium
Pb - lead

shaded areas are sweeping period data

Table A9. Runoff Particle Size Analysis Results at the Test and Control Sites

Test Site

		sand/fine break		sieve analysis (% less than)			Visual Accumulation Tube Analysis (% less than)					Sedigraph Analysis (% less than)					
Sample ID	Date	% sand	% fine	8 (mm)	4 (mm)	2 (mm)	1 (mm)	0.5 (mm)	0.25 (mm)	0.125 (mm)	0.062 (mm)	0.031 (mm)	0.016 (mm)	0.008 (mm)	0.004 (mm)	0.002 (mm)	0.001 (mm)
OK-1	3/14/99	0	100								100	98.13	91.88	76.88	62.5	45.63	-
OK-3	4/16/99	17.78	82.22	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-8	6/16/99	26.75	73.25	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-9	6/23/99	32.48	67.52	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-10	6/28/99	93.1	6.9	100	97.2	90.5	70	56.2	20.2	8.4	6.9	-	-	-	-	-	-
OK-11	7/6/99	49.07	50.93	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-12	7/9/99	97.04	2.96	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-13	7/16/99	82	18			100	85.1	72.2	44.7	33.5	18	-	-	-	-	-	-
OK-14	7/21/99	91.92	8.08	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-15	7/31/99	73.4	26.6				100	93.4	67.7	42.7	26.6	-	-	-	-	-	-
OK-16	8/7/99	73.3	26.7			100	94.4	80.8	55.8	38.2	26.7	-	-	-	-	-	-
OK-17	8/10/99	92.6	7.4		100	94.6	78.1	63.9	31.4	13.1	7.4	-	-	-	-	-	-
OK-18	8/18/99	75.5	24.5			100	93	82	55.2	39.8	24.5	-	-	-	-	-	-
OK-19	8/23/99	78.13	21.87	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-20	9/19/99	91.67	8.33	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-21	9/27/99	19.97	80.03	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-22	9/27/99	89.8	10.2			100	91.1	72.5	25.5	12.6	10.2	-	-	-	-	-	-
OK-23	10/3/99	40.9	59.1			100	80.5	76.2	69.8	66.1	59.1	-	-	-	-	-	-
OK-24	10/16/99	> 35	< 65				100	75	65	35	-	93.3	79.7	62.9	40.8	19.1	13
OK-25	11/10/99	59.3	40.7			100	87	77.3	66.6	55.5	40.7	-	-	-	-	-	-
OK-26	11/19/99	64	36			100	80.8	80.3	74.8	71.2	64	95.3	88.8	78.4	54.4	43.2	33.5
OK-27	11/23/99	37.7	62.3			100	91.6	83.6	72.9	62.6	62.3	-	-	-	-	-	-
OK-28	12/14/99	13.5	86.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-31	2/21/00	4.7	95.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-32	2/24/00	10.1	89.9									84.88	74.63	60.87	46.94	32.73	27.42
OK-33	4/7/00	19.4	80.6			100	92.9	89.5	84.7	82	80.6	-	-	-	-	-	-
OK-34	5/9/00	84.2	15.8			100	52.5	40.8	24.6	17	15.8	14.96	14.19	10.78	8.47	4.09	2.38
OK-35	5/17/00	67.8	32.2			100	62	53.1	40.3	32.8	32.2	-	-	-	-	-	-
OK-36	6/1/00	87.6	12.4			100	81.7	65.1	28.3	14.5	12.4	-	-	-	-	-	-
OK-37	6/4/00	19.9	80.1				100	90.2	82.1	80.1	80.1	-	-	-	-	-	-
OK-41	8/5/00	56.2	43.8				100	90.4	64.9	54.5	43.8	-	-	-	-	-	-
OK-42	8/17/00	34.8	65.2			100	89	78.3	72.3	69.9	65.2	-	-	-	-	-	-
OK-43	8/17/00	1.8	98.2	-	-	-	-	-	-	-	-	-	-	-	-	-	-
OK-44	8/26/00	46.8	53.2			100	91.5	80	60.8	57	53.2	-	-	-	-	-	-
OK-45	9/7/00	36.7	63.3			100	92	83.4	69	66.1	63.3	-	-	-	-	-	-
OK-46	9/10/00	66	34			100	88.4	71.5	53.6	38.9	34	-	-	-	-	-	-
OK-47	9/14/00	4.2	95.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Control site (Table A9 con't)

		sand/fine break		sieve analysis (% less than)			Visual Accumulation Tube Analysis (% less than)					Sedigraph Analysis (% less than)					
Sample ID	Date	% sand	% fine	8 (mm)	4 (mm)	2 (mm)	1 (mm)	0.5 (mm)	0.25 (mm)	0.125 (mm)	0.062 (mm)	0.031 (mm)	0.016 (mm)	0.008 (mm)	0.004 (mm)	0.002 (mm)	0.001 (mm)
NT-1	3/14/99	0	100									100	90	70	57.14	38.57	-
NT-3	4/16/99	35.69	64.31	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-8	6/16/99	18.52	81.48	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-9	6/23/99	13.1	86.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-10	6/28/99	82.1	17.9		100	78.2	78.2	65.4	36.3	21.3	17.9	-	-	-	-	-	-
NT-11	7/6/99	58.81	41.19	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-12	7/9/99	91.6	8.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-13	7/16/99	84.1	15.9			100	68.1	54.6	33.6	25.4	15.9	-	-	-	-	-	-
NT-14	7/21/99	83.56	16.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-15	7/31/99	63.3	36.7			100	90.6	89.8	71.9	53.8	36.7	-	-	-	-	-	-
NT-16	8/7/99	91.8	8.2	100	97.9	83	48.8	30.5	17.5	11.8	8.2	-	-	-	-	-	-
NT-17	8/10/99	62.5	37.5			100	91.9	85.9	60.3	48.4	37.5	-	-	-	-	-	-
NT-18	8/18/99	86.8	13.2			100	64.9	55.7	33.6	24.6	13.2	-	-	-	-	-	-
NT-19	8/23/99	27.4	72.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-20	9/19/99	88.55	11.45	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-21	9/27/99	23.94	76.06	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-22	9/27/99	83.5	16.5			100	68.5	49.3	25.9	21.2	16.5	-	-	-	-	-	-
NT-23	10/3/99	3.3	96.7					100	99.4	97.7	96.7	-	-	-	-	-	-
NT-24	10/16/99	> 31.2	< 68.8				100	90	50	31.2	-	98	84.1	78.6	48.8	33.9	24.3
NT-25	11/10/99	47.2	52.8			100	74.5	70	61.4	58.1	52.8	97.3	81.2	60.9	37.6	20.8	13.7
NT-26	11/19/99	9	91				100	99.8	96	93.6	91	92.2	88.3	77.2	57.4	32.3	24.1
NT-27	11/23/99	20	80			100	86.8	86.8	83.4	80.1	80	-	-	-	-	-	-
NT-28	12/14/99	2.4	97.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-30	2/18/00	0.72	99.3	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-31	2/21/00	1.2	98.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-33	4/7/00	2.9	97.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-34	5/9/00	31.5	68.5				100	97.7	77.5	72.6	68.5	-	-	-	-	-	-
NT-35	5/17/00	56.7	43.3			100	62.9	54.2	48.8	45.5	43.3	-	-	-	-	-	-
NT-36	6/1/00	49.5	50.5			100	80.6	70.1	53.8	50.8	50.5	-	-	-	-	-	-
NT-37	6/4/00	24.4	75.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-40	7/28/00	73.2	26.8			100	72.9	56.9	40.9	34.6	26.8	-	-	-	-	-	-
NT-42	8/17/00	16.3	83.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-43	8/17/00	1.2	98.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-44	8/26/00	38.9	61.1	-	-	-	-	-	-	-	-	-	-	-	-	-	-
NT-45	9/7/00	32.5	67.5			100	87.1	83.9	74	70.6	67.5	-	-	-	-	-	-
NT-46	9/10/00	41.6	58.4			100	86.5	75.3	64.1	58.7	58.4	-	-	-	-	-	-
NT-47	9/14/00	16.5	83.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-

-, no data

Because of new instrumentation at the lab, the shaded data shows the particle size distribution only within the 0.031mm to 0.001mm size fractions.

Table A10. Vehicle Count Data in Test and Control Sites

	Test Site		Control Site	
Event Number	Vehicle count during runoff period	Vehicle count during sampling period	Vehicle count during runoff period	Vehicle count during sampling period
1	285387	285387	491416	474611
2	47191	40918	47191	44668
3	30850	26521	26259	14345
4	54398	39183	52816	40010
5	29442	23936	28907	6515
6	37198	32884	35478	35478
7	57902	55016	56500	53128
8	14476	11370	15962	6151
9	16760	13970	16760	13281
10	23114	19514	25259	20201
11	1237	902	981	362
12	2489	1926	2558	1695
13	76666	74706	74706	63548
14	3098	3098	16313	1182
15	4833	2037	4144	1884
16	23906	19437	26105	20562
17	886	726	1030	513
18	11972	10915	13029	10056
19	17733	14498	18548	12270
20	22498	22498	32540	29383
21	11461	4188	11461	4188
22	74218	73442	74218	71654
23	65490	61450	66752	57503
24	32882	28696	12982	10213
25	20601	19321	27827	18046
26	536462	528412	542800	526419
27	9151	4337	17060	10365
28	37265	34594	39992	19966
29	-	-	-	-
30	-	-	-	-
31	80579	79730	81639	74577
32	45597	38697	35366	27771
33	75957	75957	75957	74820
34	36059	19272	37735	20987
35	33792	33792	27280	23980
36	16503	15339	54507	46223
37	72739	62947	34081	34081
38	5863	3795	8844	1902
39	14051	8160	12573	6400
40	20299	13732	21485	9601
41	43098	15560	50909	4183
42	49121	1644	50891	3038
43	11708	3486	12905	12905
44	13287	8969	8969	6981
45	16358	7674	12143	7674
46	8435	4575	8435	3531
47	40382	14946	38799	18345
48	91782	80664	86899	70860

Shaded areas mean the data is mostly or completely estimated from weekly averages